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# THE RADIO ASTRONOMER'S UNIVERSE[1]

by

PROF. A. C. B. LOVELL

WHEN Sir Norman Lockyer died in 1920 the science of astronomy was on the verge of spectacular development. The great 100-inch telescope at Mount Wilson had just been completed and this instrument soon revealed a universe whose extent would have exceeded the wildest dreams even of such a visionary as Lockyer. Although during the main phase of his career, the telescopes had revealed the existence of thousands of diffuse objects, or nebulae, these were generally regarded as being part of the Milky Way system. Estimates of the size of this system varied from 5,000 to 20,000 light-years and the sun was commonly believed to be situated near the centre of the system, until the work of Shapley and Kapteyn showed that these ideas were far too restricted. To-day we believe that the Milky Way is a vast assemblage of some hundred thousand million stars distributed throughout a disc-like system, 100,000 light-years in diameter, 20,000 light-years thick at the centre, with the sun located nearer the edge of this disc than the centre. Within four years of Lockyer's death, Hubble's remarkable work had shown beyond doubt that certain types of the nebulae were external to this system and placed at very great distances from it. He estimated our distance from the nearest one in Andromeda to be 900,000 light-years, and although this is now believed to be a slight over-estimate, the realisation that the nebula was an assemblage of stars similar in size and shape to the Milky Way system, at once showed that a great revolution in the astronomer's idea of the universe was imminent. In subsequent years the Mount Wilson telescope extended our knowledge of the universe to a distance of 500 million light-years, indicating that there were some hundred million galactic systems, similar to Andromeda and the Milky Way, distributed throughout this vast space.

It seems to be a remarkable evolutionary coincidence that man has been able to achieve this astonishing view of the universe. His eyes are sensitive only to a small part of the electromagnetic spectrum, that part including just the range of wavelengths from red to blue which penetrates the Earth's atmosphere without absorption. A being whose spectrum of vision was displaced even a small amount towards the ultra violet or infra red would never be able to see the sky and the stars, not because of any lack of radiation in these wavelengths but because the radiation would not penetrate the Earth's atmosphere. The telescopes of Mount Wilson and Palomar would then be of little use, and man's view of the universe would be no more than that which is now seen on a cloudy night. This limitation has never worried astronomers unduly. The distribution of the energy in a hot body such as a star has been well known for over half a century and it seemed clear that our knowledge of the universe was not appreciably restricted by the absorption in the atmosphere. Furthermore, a second, more extensive, gap or window in the atmosphere at much longer wavelengths was not considered to be of any interest to astronomy. This gap exists in the so-called 'radiowave region.' At the short wave end it is limited by atmospheric absorption at a wavelength of about 0·25 cm., and at the long wave end by reflection in the Heaviside layer, or ionosphere, at a wavelength of about 20 metres. Any radio waves generated on the Earth within this waveband can penetrate the atmosphere and ionosphere and escape into space. Similarly if any radiation were being generated in space in this wave band it could pass through

[1] The Norman Lockyer Lecture given in Belfast on November 28, 1951.

the Earth's atmosphere and ionosphere and be received on the Earth. There was little interest in this matter, however, because it seemed impossible that any of the objects studied by astronomers could emit detectable amounts of energy on these long wavelengths.

At the end of 1931 an American engineer, Jansky, made a most remarkable discovery. He was investigating atmospherics at the Bell Telephone laboratories on a wavelength of 15 metres, and found that the ' noise ' which his aerial system picked up showed a diurnal variation, both in direction of arrival and intensity. Jansky soon appreciated that the periodicity of this noise was not exactly 24 hours, but 23 hours 56 minutes which corresponds with the period of the Earth's rotation relative to the stars. The source of this radio noise was therefore outside the Earth. From further measurements over the next few years Jansky concluded that the maximum intensity of radio noise appeared to come from the direction of the centre of the Galaxy, and to be distributed generally along the Milky Way. He suggested that these radio waves were being generated either in the stars or in interstellar space. In retrospect, it appears strange that Jansky's discovery received so little attention. His work was followed up by one or two workers, notably by Reber in America between 1940 and 1944, but it was not until the years immediately following the second world war that the great astronomical significance of his discovery was realised. Before discussing the surprising discoveries which were then made it may be appropriate to describe the type of apparatus which is used by the radio astronomer.

The principal tool of the astronomer is his telescope ; likewise the radio telescope is the principal tool of the radio astronomer. The optical telescope collects and focuses light of wavelengths in the region of 50 millionths of a centimetre ; the radio telescope has to deal with radio waves from a few centimetres to several metres in wavelength. Hence the wavelength change is of the order of a million times and the difference in nature of the two types of telescope reflects this big change. The giant 200-inch telescope on Mount Palomar is by far the largest conventional telescope so far envisaged ; but there are several radio telescopes in existence with diameters of 300 to 400 inches (see Fig. 1). The radio telescope is easier to construct because of the long wavelength radiation which it collects, enabling an open wire mesh surface to be used. Whereas the mirror of the optical telescope has to be figured to an extremely high degree of accuracy, that of the radio telescope can be comparatively crude—errors in shape of a few inches are quite permissible when wavelengths of a few metres are used. One of the great difficulties of the radio astronomer is that the long wavelengths mean that the resolving power of his instrument is hopelessly inferior to that of the optical telescopes of equivalent size. One of the largest radio telescopes ever constructed, shown in Fig. 2, has a diameter of 220 feet, but when used on a wavelength of 2 metres it receives radiation in a beam 2 degrees wide and hence, in principle, could only resolve an object with an apparent diameter four times that of the sun—a very inferior resolution even in comparison with a poor optical telescope.

The human eye, or the camera, is normally placed at the focus of the optical telescope, but in the radio telescope the focus is occupied by a simple aerial system of the type which can be seen in the photographs of Figures 1 and 2. The received radio signals pass from this aerial along wire feeders to the radio receiver itself where they are recorded and measured by apparatus which is in many ways similar to a television receiver. Permanent records are generally obtained by using pen recorders, which yield details of the signal strength against time for the part of the sky to which the radio telescope is directed.

It was with apparatus of this general type that Jansky made his surprising discovery that radio waves were reaching the Earth from outer space. Reber's instrument was more refined and in the years following 1940 he used a radio telescope very similar to the 30-foot one shown in Fig. 1. This gave a beam width of 12 degrees when used on a wavelength of 2 metres, and with it he was able to explore in some detail the strength of the radio emission coming from different directions in the Galaxy. He found that

FIG. 1.—The 30-foot aperture steerable radio telescope at the Jodrell Bank Experimental Station, Cheshire. The short rods at the focus of the instrument determine the wavelength—about 3·8 metres for those shown in the illustration. (*Photograph by A. Maxwell.*)

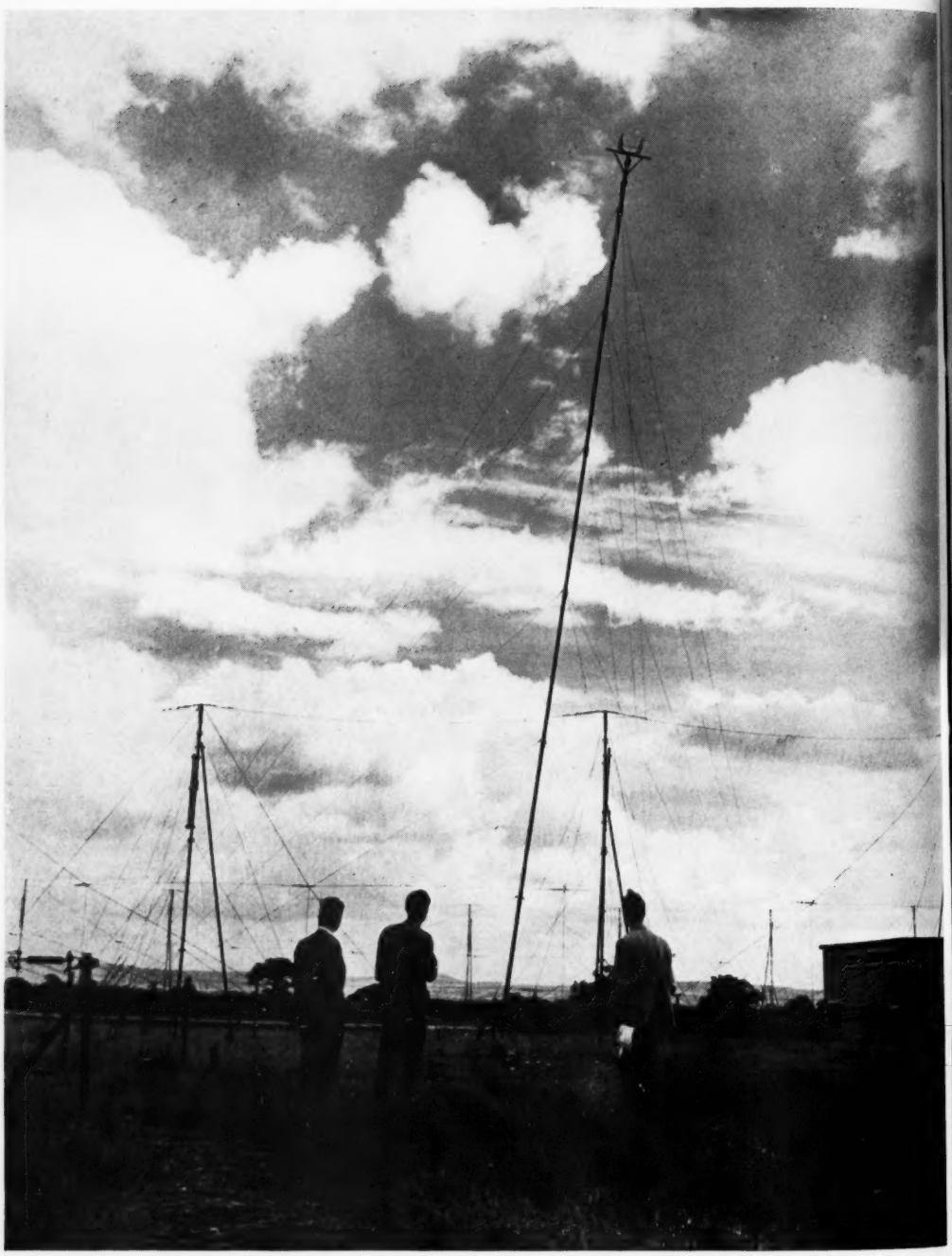

FIG. 2.—The 220-foot aperture radio telescope at Jodrell Bank. The bowl is formed of many miles of thin wire held in the shape of a paraboloid. The aerials at the focus are carried on the mast 126 feet above ground level. This instrument is fixed but the beam can be swung up to 14 degrees from the vertical by tilting the mast as shown in the illustration. (Crown Copyright—reproduced by kind permission of the Central Office of Information.)

FIG. 3

FIGS. 3 and 4

The Great Nebula in Andromeda (M.31) as seen by the astronomer (FIG. 3) and the radio astronomer (FIG. 4).

FIG. 3 is a photograph of the nebula taken with the 48-inch Schmidt telescope at Mt. Palomar. It is reproduced by kind permission of the Mount Wilson and Palomar Observatories.

FIG. 4 is a facsimile of a single record of the radio emission obtained as the beam of the radio telescope (shown in FIG. 2) sweeps over the nebula. This record was obtained by Hanbury Brown and Hazard and is reproduced by kind permission of the editors of the *Monthly Notices of the Royal Astronomical Society*.

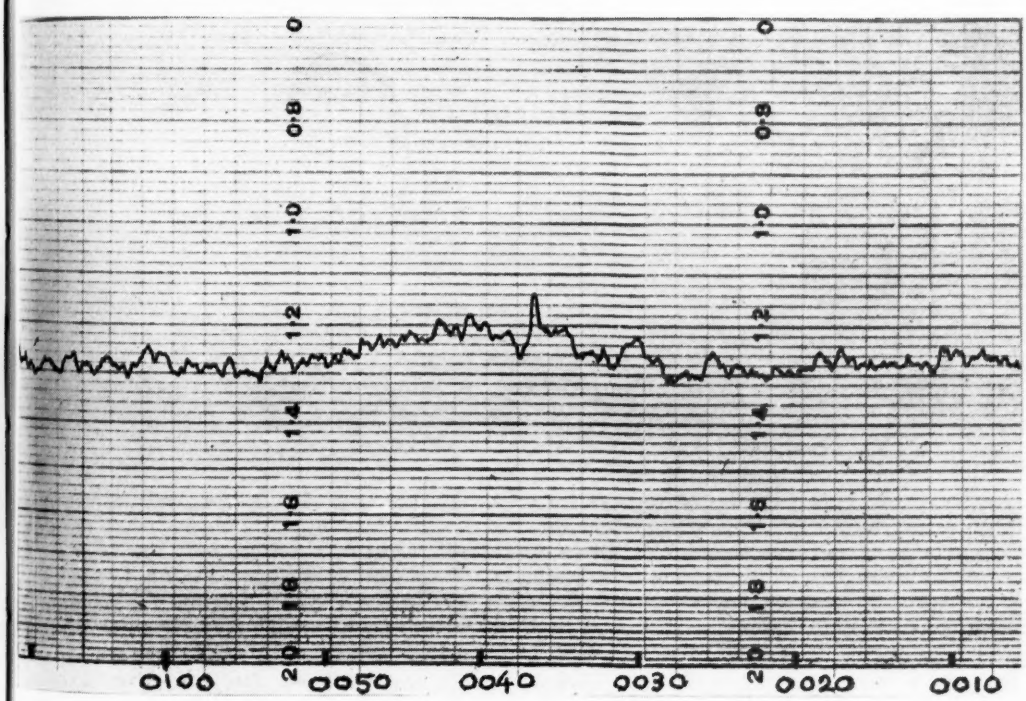


FIG. 4

the radio signals were strongest when his aerial was directed along the plane of the Milky Way and that the maximum intensity came from the direction of the centre of the Galaxy. In fact, the contours of the radio emission corresponded quite well with the known distribution of stellar density in the Milky Way system, and at first sight it seemed possible that these radio waves might be coming from the stars. But when Reber directed his radio telescope at the brighter and more conspicuous individual stars in the sky he obtained no specific increase in signal strength; neither could he find any particular visual object in the sky which gave him a definite signal. He finally concluded that the radio waves were not coming from the stars, but were being generated by some atomic process in the highly rarefied gas of interstellar space. This was the belief which existed at the end of the second world war, and there was then little indication of the surprising facts which were soon to emerge.

One of the first indications of anything unusual in these radio emissions arose from some measurements made by Hey and his colleagues in Great Britain immediately after the war. They used a somewhat longer wavelength than Reber and confirmed his general conclusions regarding the distribution in intensity of the emissions in the Milky Way. They noted one peculiar feature—the signal strength from the region of the sky near Cygnus showed irregular fluctuations with periods of seconds or minutes. Hey concluded that this must be due to the presence of a high-intensity variable source in Cygnus, but because of the breadth of his aerial beam he was unable either to verify this idea or position the suspected source with any precision. Meanwhile Bolton and Stanley in Sydney, and Ryle and Smith in Cambridge had developed a type of radio telescope which, to a certain extent, overcame the severest difficulties of resolution. In principle these systems used two separate aerials spaced by several hundred metres; the signals from the two aerials being connected to the common input of a radio receiver. Whereas the reception pattern of a single aerial consists of a main broad lobe which narrows as the size of the aerial is increased; the reception pattern of these spaced aerial 'interferometers' consists of a close-packed system of lobes, resembling the corrugations of a fan. As the Earth rotates and this lobe system sweeps over the sky, the intensity of the signal in the receiver output will remain steady, or vary slowly, provided the source of the radiation subtends an angle large compared with the separation of the lobes. If, however, the radio signals are coming from a source which subtends an angle small compared with the lobe separation, then the signal at the receiver output will go through a series of maxima and minima. The systems used in Sydney and Cambridge differed slightly. The Australian workers mounted one aerial on a high cliff overlooking the sea and obtained their lobe system by virtue of the interference of the ray received directly by the aerial and that reflected via the surface of the sea. The system has an analogy in light—the Lloyd's mirror interferometer. The British workers used two separate aerials on the ground, thus simulating another well-known optical device—Michelson's stellar interferometer which consisted of two mirrors, separated by several feet, reflecting the light from a star into the 100-inch Mount Wilson telescope. From the interference pattern thus produced he was able to carry out his classical measurements of the diameters of some of the nearer stars—the smallest one measured being Arcturus with a diameter of 0·02 seconds of arc.

In 1948 both groups of workers in Sydney and Cambridge used their radio interferometers to study the radio emissions from the Galaxy with the most startling results. Firstly from Sydney, Bolton and Stanley announced that they had found an intense source of radio emission with an angular diameter of less than 8 minutes of arc in the constellation of Cygnus. Shortly afterwards Ryle and Smith discovered an even more intense source in Cassiopeia. The most remarkable feature of this work was not so much the discovery of localised sources of intense radio emission, but the complete inability to identify them with any particular visual objects in the sky. Although lacking the precision of optical telescopes, the radio interferometers can position these intense

sources with considerable accuracy. In the region of space containing the Cygnus and Cassiopeia sources there are, of course, many visible stars, but none of outstanding visual characteristics. In fact, the most recent conclusion is that no star brighter than 16th or 17th magnitude is near either the Cygnus or Cassiopeia radio source. Since the original work in 1948 many more of these localised sources of radio emissions, or radio stars, have been located, but no one has yet been able to identify any object or class of visual objects in the Galaxy with the source of these radio emissions.

The question arises immediately as to the number of these radio stars contained in the Galaxy. So far, the number discovered has increased with improvements in the sensitivity of the radio equipment. The answer as to how long this process of discovery will continue is not known, but the most plausible speculation is that the hundred or so now known are merely the nearest and most intense of a very large number in the Galaxy. With the unaided eye, or with a small telescope, the Milky Way appears as a diffuse patch of light. It is only with the larger instruments that this diffuse appearance can be seen to be due to the existence of myriads of stars. We now believe that a similar situation exists with the radio stars, and that the radiation which we receive from the direction of the Milky Way appears diffuse because our contemporary radio telescopes are not good enough to resolve it into radio stars. From the strength of this unresolved emission and from the strength of the signals received from the known radio stars it is possible to make an intelligent guess at the total number of radio stars in the Galaxy. The answer is very surprising—the population of radio stars in the Galaxy must be very similar to the population of the visible stars. The paradox is astonishing. The Galaxy contains some hundred thousand million stars which emit light and can be seen with the human eye and telescope. Does it also contain a similarly vast number of dark objects which generate intense radio waves and can only be seen by the radio telescope? It is a large extrapolation from a few hundred known radio stars to a possible thousand million not yet resolved, but at present the answer cannot be seriously doubted. It is a situation which would have delighted Lockyer, and his own views on this matter can be readily imagined.

The problem of the nature of these radio stars is one of the most puzzling in present-day astrophysics. It seems certain that they are not associated with any prominent visual objects in the Galaxy. If they are star-like bodies, then they must be dark objects which possess certain electrical and magnetic properties enabling them to generate these intense long wave emissions without producing much energy in the visible part of the spectrum. They could conceivably be dwarfs which have exhausted their hydrogen and, in a late stage of existence have achieved unusual rotational and electromagnetic properties. Or, on the contrary they may be diffuse gas-like objects ; perhaps stars in the early stages of formation and still at low temperatures. Neither can the possibility of a new type of electromagnetic stellar object, of which we have no previous experience, be excluded. There seems little immediate prospect of much clarification of these problems. The long wavelengths militate against the accurate measurements which are so necessary. For example, there is no certain information about such fundamental matters as the distance or size of these radio stars. The most accurate parallax measurements which it has yet been possible to make are those made by Ryle in Cambridge. These only suffice to place the most intense, and therefore presumably the nearest, radio stars outside the solar system! In the case of the diameters these can be measured in principle from the ratio of the maximum to minimum in the interference pattern of the radio interferometer—as Michelson calculated those of the visible stars in his stellar interferometer. This can only be done if the angular separation of the lobes in the interferometer can be made comparable with the angular diameter of the radio star, and this entails far greater separation between the aerials of the interferometer than it has yet been possible to achieve. Michelson separated the mirrors of his stellar interferometer by 24 feet, and measured the diameter of the star Arcturus as 0·02 seconds of arc. His

wavelength was $5{\cdot}7 \times 10^{-5}$ cm. The wavelength of the radio interferometer is about 2 metres and hence the equivalent separation of the aerials would have to be about 4 million times greater, or nearly 20,000 miles! In practice, technical problems have so far made it impossible to separate the aerials by even a mile, and the extent of our knowledge about the diameters of the radio stars is only that they are less than 6 minutes of arc. Although this measurement represents a first-class technical achievement, the resulting limit is 3,000 times greater than the angular diameter of the brightest visible stars. Hence it is possible that the radio stars extend over vast areas of space compared with the 'points' which we recognise as visible stars. It is difficult to see how the radio star paradox can be resolved until these fundamental measurements are made. They present themselves as a severe technical challenge to the radio astronomer, and as one of the most fascinating tasks for the coming decade from which striking advances in cosmology may be anticipated.

Is the Milky Way system unique in the generation of these radio emissions? Or do the external nebulae also contain radio stars? Several workers sought for the answer to this problem but without success until 1950. Even as early as 1940, Reber, during the course of an inspection of all likely sources, directed his radio telescope at the nearest external system in Andromeda, but failed to find any radio emission from it. However, during 1947, the great 220-foot aperture radio telescope shown in Fig. 2 was completed at Jodrell Bank and used in the study of the galactic radio emissions. This instrument possessed a sensitivity far in excess of any other radio telescope in the world, and in the spring of 1950 Hanbury Brown considered the possibility of detecting radio emissions from the Andromeda nebula with it. Taking into consideration the relative size of the Milky Way system and Andromeda, and assuming that the emission of radio waves was similar in the two systems, it was possible to calculate the intensity of the signal which one might expect to obtain on the Earth. The calculations indicated that the emissions from the nebula might just be on the limits of detection using the large radio telescope and the most sensitive receiving equipment available. The radio telescope itself was designed to look towards the zenith, but by tilting the mast holding the primary feed at the focus it was possible to displace the beam. By a most fortunate chance the Andromeda nebula just lay within the field of the instrument at its extreme displacement of 14 degrees from the zenith. In a series of refined measurements made during the summer and autumn of 1950 Hanbury Brown and Hazard succeeded in recording the radio emissions from the nebula. The delicacy of the measurement can be gauged from the fact that the strength of the signal was 300 times less than that received from the radio star in Cassiopeia, and 1,500 times less than the radio noise generated in the receiving system itself! The appearance of the emissions from the nebula on the recording chart is shown in Fig. 4. These slight displacements of the pen on the recording chart, which were repeated every night as the movement of the Earth swept the beam of the radio telescope across the nebula, proved beyond reasonable doubt, that not only light but radio waves also, were being generated in this remote nebula and were reaching the Earth after traversing the depths of space for nearly a million years.

The implications of this experiment are far-reaching. The only reasonable conclusion is that the radio stars must populate the Andromeda nebula as well as the Milky Way system, and a comparison of the total radio emissions of the two stellar systems indicates that their radio star population must be very similar. These are merely two nebulae in an assemblage of millions of similar ones scattered throughout the universe. It therefore seems highly probable that the objects which generate these radio emissions exist in all the external nebulae, and the most recent experiments strongly support this view. The detection of the radio emission from the Andromeda nebula with the large radio telescope has recently been followed by the measurement of similar emissions from five other individual nebulae, both with the radio telescope at Jodrell Bank and with the radio interferometer at Cambridge. Perhaps even more significant is the detection

by Hanbury Brown and Hazard of the radio emissions from two great clusters of nebulae which are far too closely grouped to be resolved individually by the beam of the radio telescope. We do not know how many radio stars there are in the Milky Way; there are certainly several hundred and there may be a thousand million. In any case the number is insignificant compared with the total population of radio stars in all the nebulae in the universe. The numbers of radio stars cease to have meaning but the paradox of their existence remains unresolved.

It must now be clear that the radio astronomer's universe is beginning to bear a marked similarity to the astronomer's universe. Although his vision is poor and diffuse he has the great advantage of being untroubled by the obscuration of clouds and atmospheric dust. The English countryside is as good a place for his radio telescope as the high mountain of Palomar. With it he 'sees' stars and galaxies which bear a striking resemblance to the universe of everyday experience. The bright stars are found in different parts of the sky—Cassiopeia and Cygnus instead of Sirius and Capella. The diffuse background of the Milky Way is there as a band of 'radio light' in place of starlight, and beyond his Milky Way system he sees the external nebulae. A being with radio eyes on the Earth would by no means be blind, he would find much to discuss with a human astronomer!

Would he also see the sun? When Jansky was convinced that the radio waves were coming from the stars it was natural for him to direct his radio telescope at the nearest star—the sun. He found no effect. Neither did Reber in 1940, although two years later both Reber and Southworth succeeded in detecting the radio emissions from the sun. The sun was the central feature of Lockyer's career. He first applied the spectroscope to solar studies and was rewarded with the discovery of helium. With Janssen he shared the excitement of proving that the 'red flames' seen around the edge of the moon during an eclipse belonged to the sun—the solar corona. Certainly no imagination is needed to appreciate how eagerly Lockyer would have seized on the radio telescope. With the radio astronomer's contemporary instruments he would always be able to see the sun; neither winter nor clouds could spoil his view.

The radio sun is much larger than the visual sun. Normally a considerable source of the radio energy comes from the corona, so that the 'red flames' which Lockyer could only see during an eclipse actually form the extremities of the sun for the radio astronomer. In the same way that the solar surface is often disturbed by spots and flares, so the radio sun is simultaneously disturbed. That tremendous outbursts of radio energy accompanied the appearance of spots and flares was appreciated by Appleton and Hey in 1945, and a few years later the use of the radio interferometer showed that the source of these radio outbursts was actually in the sunspot itself. It is interesting to recall that the radio interferometers were actually first devised by Ryle and Vonberg to study this solar sunspot radio phenomena, and were only later applied to the radio star problem. Although these new radio studies of the sun have progressed with such great speed there is still no unified picture of how the intense outbursts are generated in the sunspots and solar flares. The case of the undisturbed sun is in a different category. There seems little doubt that the 'quiet sun' radio emission originates by thermal processes in the solar atmosphere, but some other, as yet unknown, mechanism must be the cause of the far more violent output from the sunspots and flares. The flare radio emission occurs simultaneously with the development of the visual flare and is the first terrestrial evidence of the solar eruption which, within 24 hours, gives rise to the beautiful spectacle of the aurora borealis, and makes chaos of the Earth's radio communications. The relation of these outbursts to the whole process of solar-terrestrial phenomena forms one of the most important and fascinating problems in solar physics.

It needs little insight to appreciate how eagerly Lockyer would have seized on the new instruments of the radio astronomer to study this radio universe. But perhaps his imagination would have been stirred most by the ability of the new techniques to study meteors—a subject associated with the greatest speculative effort of his

career. The Leonid meteor showers of November 1833 and 1866 were amongst the most tremendous celestial displays in history, and Lockyer, at the age of 30, was privileged to watch the display of 1866. In the view of his biographers the effect of this display made a deep and lasting impression on his mind, especially as another startling event—the appearance of a new star, T Coronae—had occurred earlier in the year. His interest was further stimulated by Coggia's comet in 1874, the appearance of which led him to resuscitate an older idea that a comet consisted of swarms of meteors. Then in 1876 Nova Cygni appeared, an event which rapidly led him to the full development of his meteoric hypothesis, the central idea of which was that all self-luminous bodies in the celestial spaces were composed either of swarms of meteorites or of masses of meteoritic vapour produced by heat.

Lockyer evolved this meteoric theory of the origin of the universe just at the time when the brilliant work of Schiaparelli and H. A. Newton had shown that some of the well-known meteor displays were the result of the Earth passing through debris which was moving in the orbits of comets. After that the development of the science of meteor astronomy was slow. It was known that millions of meteors were burnt up each day as they rushed into the Earth's atmosphere, but there was no test as to whether the ' meteoric plenum ' existed throughout the whole of space as imagined by Lockyer. The development of the subject was seriously handicapped by the hindrances to systematic observation caused by unfavourable sky conditions, but during the last few years the radio astronomer has been able to observe the reflection of radio waves from trails of meteors. Pulses of radio waves are transmitted from the earth and the energy scattered from the ionised trails of the meteors can be detected on sensitive receivers as transient echoes. Methods now exist for measuring the very high speeds with which these tiny particles enter the atmosphere and for plotting the orbits which they are pursuing in space. The phenomena in the sky are no longer obscured either by clouds or daylight. The revelation in the day-time sky has been particularly striking. From May to August the day-time meteor activity is now known to exceed any of the night-time events in intensity and persistence. Each year during these summer months the earth passes through a vast amount of meteoric debris, which is moving in a sequence of orbits around the sun in such a way that the meteors enter only the sunlit hemisphere. The orbits are unlike those of some of the night-time streams. Whereas a particle in the Leonid orbit takes 33 years to complete its journey around the sun, the particles in these summer day-time meteor orbits take only 2 or 3 years. They lie inside the orbit of Jupiter, and although their origin is not yet known it seems that they must have a closer association with minor planets than with comets. This discovery would certainly have intrigued and excited Lockyer, although he would, perhaps, have been saddened by the radio astronomer's insistence that the meteoric plenum which his theory required to exist through the depths of space is, in fact, limited to the solar system.

Lockyer ended his distinguished career in less glory than one could have hoped. His plans for the Government to provide and support a national observatory worthy of his great discoveries were finally frustrated. The small observatory on Sidmouth hill which he created in the autumn of his life after this disillusionment, only remains as a monument to his spirit. At the time of Lockyer's death, observational astronomy in Great Britain was rapidly losing its claim to pre-eminence in the face of the creation of the giant American telescopes. It is a consolation to record on the occasion of this memorial lecture that the British radio astronomers are not lacking the support of their country. The largest radio telescope in the world rises from the British countryside, and the universe which it reveals can, indeed, claim comparison with that seen from Mount Palomar.

# CULTURAL CONTACTS IN EDUCATION[1]

by

PROF. MARGARET READ

EDUCATION in its broadest aspect is a process of cultural contact. All individuals, whether children or adults, learn, and by so doing acquire an education, through contact with such sources of culture as books, personalities, social and political institutions, historical sites and monuments. Some of these contacts are with contemporary culture, some with the culture of the past; some of them are with indigenous national cultures, some with foreign cultures. The contacts may be systematised and formal, and promoted by recognised instructional methods; or they may be casual and informal, and achieved through individual initiative and self-directed activities. In this sense the Festival of Britain presents our national culture, historic and contemporary, to our own people, as well as to the foreign visitors who flock to the Exhibitions and Festival Weeks; and this presentation takes place through direct instruction and through self-directed activities.

The first necessity in a paper on some aspects of this wide field is to establish agreement about the meaning and use of the term *culture*. I propose to use the concept of culture as it has been developed in the writings and research of social anthropologists. It is used by them to denote patterns of behaviour, methods of earning a living, forms of law and government, kinship and family structure, modes of thought, and the value-attitude systems inherent in any people's way of living. Thus social anthropologists can speak of the culture of a Welsh valley, as described by Mr. A. D. Rees in *Life in a Welsh Countryside;* of a Maya Indian village as described by Professor Redfield in *The Folk Culture of Yucatan;* of the Chinese ricelands in the Lower Yangtse valley as described by Professor H. T. Fei in *Peasant Life in China;* of the Baganda Kingdom in East Africa as described by Dr. Lucy Mair in *An African People in the Twentieth Century.*

In using the term *culture* in this anthropological sense we should be aware of three important provisos. The first is that the culture of a people, as in the examples quoted, in Wales, Yucatan, China or Uganda, is not necessarily homogeneous or in the strict sense of the word indigenous. It may be, and in all the above cases it is, a compound of different elements, ethnic, social, political, religious, economic, acquired over a period of time and moulded into a way of living which is not necessarily harmonious or without stress. The second proviso follows from the first; that a people's culture is never static. It is constantly changing as a result of external and internal stimuli. We shall be examining later in this paper some of the external stimuli which arise from contact with other foreign cultures through the introduction of a modern educational system. The third proviso is that in the use of this anthropological concept of culture we imply no value judgment. For the purpose of this paper we are not going to discuss whether one culture is 'higher' than another, though the relative dominance of some cultures over others is established by history, and some cultures, particularly those of pre-literate peoples, are more vulnerable to outside influences than others. For these reasons culture is a more satisfactory term to use in this context than civilisation. There will therefore be no reference to civilised or uncivilised peoples, nor to the process of 'civilising.' The concept of culture will be used in an objective as well as in a comprehensive connotation, and culture contacts and cultural change will be discussed from this point of view.

Still following the lead of the social

[1] Paper read before the Education Section at Edinburgh on August 14, 1951.

anthropologists we can now proceed to link culture, as just defined, with education. A number of anthropological writers, who have studied pre-literate societies, have defined education in those societies as the process of transmitting a people's culture from one generation to the next. This theme has been elaborated by Professor Fortes, Dr. Edwin Smith, Dr. Otto Raum, and Dr. Childs in the African field, and by a number of writers on the Pacific and North America. The titles of two recent studies among the North American Indians illustrate this by their very phrasing: *The Hopi Way; The Navajo Door*. Another study in the Pacific, *Becoming a Kuoma*, suggests the same idea. In these and other parallel studies, the emphasis is on the process by which a child, born into a society possessing a certain culture, which is his by right of birth and inheritance, nevertheless has to go through a training which may be informal as well as formal, in the course of which he recognises the Hopi Way, goes through the Navajo Door, learns to be a Kuoma although he was born one.

We should admit at once that this linking of culture and education, that is regarding education as the transmission of culture, is on the whole foreign to our way of thinking about education in Western Europe. We have been accustomed to limit the use of the term education to formal instruction in a system of schools, and, until recent years when new educational methods have been experimented with, to the acquiring of knowledge through books. If we were to ask ourselves, or if strangers were to inquire of us, how a child, born and bred in one of the nations of the United Kingdom, learns to recognise the English Way, to go through the Scottish Door, to become a Welshman, we should have no ready answer. We might attempt to explain the subjects included in the curriculum of our schools; or we might attempt to discover for ourselves a synthesis of these subjects in terms of our contemporary and historic culture. We might talk about Civics or Citizenship or Social Studies, implying that we have had to invent new subjects or give new names to old subjects, in order to relate learning in school to learning about the wider world outside school. It is true that recent educational reports have emphasised the importance of relating the subjects taught in the curriculum, as well as the methods of teaching them, to the environmental background of the children, that is to the culture to which they belong. We are well aware, however, that children learn their patterns of social behaviour, their ideas on family life and earning a living, their value-attitude systems in relation to social and economic life, far more intensively and extensively outside school than inside. To the extent to which this is true, and in so far as we habitually consider education in terms of schooling only, we are unable to answer inquiries about whether education can be thought of as a means of handing on our own culture.

It might be argued here that our British concept of freedom, and of the role of the individual in a free society, prevents us from placing much emphasis on the English Way, or the Scottish, or the Welsh, in our training of young people. We are further deterred perhaps from taking such a line because of what we have seen and know of the results of political and social indoctrination under the totalitarian powers. Yet another deterrent may be the impulse to-day to give young people an international outlook instead of a narrowly national one. All these are points of view which deserve consideration in the relationship of education and culture in the United Kindom. They do not, however, explain why we apparently do not regard our educational system as the means of transmitting our own culture to the next generation.

Sir Fred Clarke has suggested in his *Education and Social Change* that we ought to examine the varied types of educational institutions in England and analyse the extent to which they express certain characteristics of the English way of living and thinking. Let us consider for example a grammar school in a dock area in London where some of the sixth form boys are prepared for the university. They learn, among other things, Latin and Greek, ancient and modern history, the appreciation of art, drama and music, and the practice of physical fitness through athletics and games. Such a situation, examined from a sociological angle, poses

the problem of a culture deliberately set up within another culture, and illustrates certain results of cultural contact through school education. In this dock area with its characteristic economy, its patterns of family living, forms of recreation, modes of thought and sense of values, the boys in this grammar school are creating their own 'oasis' of another, and it would appear almost an alien, culture. Inside the school, planning for future jobs, leisure-time occupations, modes of thought and sense of values are almost entirely foreign to those of their families and neighbours. A study for a doctoral thesis was made recently of just such a situation by an educationist from one of the Dominions who had had anthropological training.

Such a study is unfortunately a very rare example of sociological analysis applied to education within our own society and culture. Hence we have no parallel data based on studies in the United Kingdom to compare with studies in other countries. We are unable therefore, as Sir Fred Clarke reminded us, to make a full assessment of the effect of a particular type of school, a secondary grammar school for example, on the individuals who pass through it, and on the local society to which those boys and girls belong and in whose pattern of living they have been brought up. Professor Ralph Linton of Yale University, in his *Cultural Background of Personality*, emphasised the point that all cultural institutions have a dual effect: on the society of which they form a part; and on the individuals who pass through them. In the United Kingdom we have become accustomed to thinking of education as a process of social change. We seldom consider it as a means of achieving cultural continuity or of building social stability and cohesion.

These are important problems of educational research in our own cultures in the United Kingdom. Without answers to these problems much of the educational planning lacks foundations. They may appear as problems of individual adjustment when the boys and girls of our schools, one by one, go out to earn their living and to take part in other adult activities of many kinds, social, political, recreational, religious. They may appear as problems of assessment of our schools' contribution to the stability and cohesion of our three nations, with their changing class structure; to our national institutions which embody democratic principles, both parliamentary and local government; and to our national standards of ethics and behaviour in public and in private life. These problems may also appear in terms of educational administration and expenditure, since planning and the provision of funds determine the type, the siting and the impact of different schools on the society in which they operate. The need for this kind of research is brought home to us by the disturbing indications that we are failing, to some extent, in the training of the young people of the national cultures which together make up the United Kingdom. The increase in delinquency, the lowering of standards in the care of public property and in sexual behaviour, the irresponsibility in the spending of money: these are some of the indications of our failure.

We have been thinking so far about the national groups making up the United Kingdom, with their relatively homogeneous cultures and unified racial stock, their long literary and historic tradition, and their established system of schools. We turn now from the problems of education and cultural contact here, where education has its roots in our culture, to the countries where a dominant culture from outside has brought a modern form of education into a traditional culture. There is one set of conditions, seen chiefly in the Orient, where a dominant European culture has introduced modern schools into countries having an ancient literary and historic tradition. Another, and a very different, set of conditions exists in most of Africa and the Pacific, where the dominant European culture has been in contact with pre-literate peoples whose traditions are preserved in oral forms only. We learn much about the impact of a dominant European culture from the history of education in India and Pakistan. We see for example how modern schooling was one of the main aspects of culture change and of the growth of individualism, whereas such training in the indigenous culture as survived was a means of

preserving cultural continuity and social cohesion on the traditional pattern.

It is very difficult to dissociate the concept of a dominant culture from political power and economic supremacy. If we recall the general definition of culture as already given, it is possible to see how a culture which is associated with political power and economic supremacy can gradually push aside another until through successive stages it either ousts the other culture or achieves a fusion in which it is the leading partner. The study of the process of 'Americanisation' of the Negro and Indian peoples of the U.S.A. suggests some aspects of this cultural dominance. A study of the cultural impact of France and of Britain in their African colonies suggests two other and two very distinctive, aspects of the process.

In order to understand these problems better we will focus our attention on the relation of a dominant culture to the culture of a formerly pre-literate people. This is the situation in most of the British African colonies.

In these African territories modern education is only one element in the general process of culture change which has been going on since the first European contacts. Education began early, it has been a continouus and persistent feature of culture change, and its extent and its effects have spread rapidly in the last thirty years. Social anthropologists who have studied the problems of culture change have called attention to the effects of modern schooling, usually to point out its disintegrating results on tribal communities and tribal culture. Certain anthropologists, among them Dr. E. W. Smith and the late Professor Malinowski, have urged that modern schooling should not be wholly divorced from the African cultural background. Professor Malinowski's article in the 'International Review of Missions' called 'Native Education and Culture Contact' was an example of this approach.

Before we look further into the doubts which have been expressed about the content and results of modern education in British Tropical Africa, we should glance at the chief cultural changes which it has brought about. In the first place these pre-literate people have learned the skills of reading and writing. Many of their languages have been reduced to writing, and an increasing stream of vernacular literature is coming from African writers. English has been introduced not only as a lingua franca among the tribal languages, but as a vital means of communication with Europeans. The degree to which this is taking place, that is African writing in the vernacular, together with ease in the use of English, varies in every territory and is most highly developed in West Africa where the earliest schools were founded. In addition to literacy and a European language, the schools, through the missionary societies who are still responsible for some 85 per cent. of them, have taught one of the world's great religions with its system of Christian ethics. The founding of churches and the impact of Christianity on family and social life has, in the non-Islamic parts of Africa, brought widespread cultural changes. Again, it is due to the schools that Africans have been able to take part in the economic development of their territories, and political advance has been made possible from the educated leadership which has come from the schools.

In the midst of much criticism about education in Africa, it is important to keep a sense of proportion about its achievements. These can partly be assessed through detailed research into the history of education in each of the territories—research which is just beginning to yield significant results. It can also be assessed through the widespread interest of the African peoples in modern education, and their determination, in West Africa at least, to reach universal schooling for all children as soon as possible.

It has been characteristic of educational planning and educational thinking in most countries during this century that the content of the curriculum in all types of schools has been constantly open to attack, and hence from time to time under review. In the earliest contacts of British educationists with African peoples, they were confident that they were bringing a superior as well as a dominant culture with them, and they proceded to teach their religion, the three Rs and new forms

of social life. It was not until after the first World War that any widespread serious doubts arose about educational policy and the content of the curriculum. With the exception of reducing the vernacular languages to writing and teaching them in primary schools, it had been assumed that the cultural contact in education would be all in one direction —towards the dominant culture. Two official Colonial Office papers, one published in 1925 and one in 1935, raised publicly the question of the divorce of modern schooling from African culture, and its disintegrating effect upon the African communities. Phrases were used in these documents such as : ' the need to improve what is sound in indigenous tradition ' ; ' education should strengthen the feeling of responsibility to the tribal community ' ; ' its aim should be to render the individual more efficient . . . and to promote the advancement of the community as a whole.'

In his book *The Dynamics of Culture Change*, Professor Malinowski sets out certain scientific principles for the study of culture change. In an accompanying diagram, he suggests that for the dominant culture (though the phrase is mine, not his) the interests and intentions of the European promoters of change should be analysed, as well as the processes and institutions by which culture change is effected. This emphasis on intentions as well as institutions is particularly important in the study of modern education as part of the process of culture change. The small amount of research that has been done so far has revealed statements by mission boards, local councils, Governors, Inspectors of schools which all throw light on the contemporary intentions in the founding of schools, the framing of the curriculum and the attainment of standards in education. It is relatively easy to count the number of schools at any time and so to measure for each decade the increase in the number of schools and the children attending them. It is more difficult, but more significant in any assessment of results, to find out why a particular curriculum was laid down ; why a certain policy about language was adopted ; why handwork and practical training gave way before an increasing emphasis on literary skills. This historical research is important at the present time, since the intentions of educational planners are often challenged, if they suggest new forms of educational institutions and new emphasis in the content of schooling. As Professor Malinowksi suggested in his study, the African peoples also have their interests in and intentions regarding the changes which have been or are about to be introduced by the dominant culture, and this is particularly true in the field of education.

There is much work to be done by other social scientists as well as by the anthropologists in clarifying and analysing the problems of cultural contact and culture change. In this field the part played by education as a means of contact with a foreign culture is, as we have seen, one of the leading issues. It is relatively easy to assemble the factual material on the part played by education in culture change. It is a formidable task to analyse this material and interpret it in relation to the general problems of cultural contact.

As a working hypothesis I suggest that we can recognise six stages in the cultural contacts of Britain with the colonial territories in Africa in the field of modern education. These stages have a chronological sequence, but since modern education is at different levels of development in different territories, and even within different parts of any single territory, we cannot say that any one territory as a whole has passed through all six stages. It is a technique for recognising, and perhaps for classifying, certain elements in the reactions of the African peoples to the impact of modern education. The earliest stages call mainly for a historical approach ; the contemporary ones for combined study by anthropologists, sociologists and psychologists. One difficulty in indicating the stages is the two-sided nature of the education pattern : the dominant culture and the traditional culture in contact in the schools and other educational institutions. It ought to be possible, in order to clarify each stage, to indicate the reaction of the dominant culture, as well as the reaction of the traditional culture, to the contacts in the field of education. This cannot be done until more research has been undertaken, hence the emphasis in this analysis will be on the reactions of the

traditional African culture. Another difficulty arises since it is virtually impossible to isolate cultural contact through education from the forms of contact in other spheres—political, economic, and religious. This is particularly true of the religious contacts, since the earliest schools were in most areas mission schools. With these two cautions on the use of this hypothesis, we can proceed to indicate the six stages.

The first stage in the attempt of the dominant culture to introduce schools was marked by conservatism among the Africans towards this new form of education. In some areas, among certain tribal peoples there was resistance to the schools, which led in Uganda to open conflict. The history of the Livingstonia Mission in Nyasaland among the warlike Ngoni people illustrates the conservatism of a people who had their own forms of training their young people. The Ngoni Paramount Chief told Dr. Robert Laws and his colleagues at first that they could live among them, practise medicine, preach on Sundays, but not 'spoil the young people' by teaching them in schools. The assurance given by Lord Lugard to the Hausa Emirs in Northern Nigeria that mission schools should not be started among their people was an acknowledgment of the deep-rooted resistance to this form of cultural contact.

The second stage is characterised by a gradual acceptance by the Africans of some of the new ideas and new ways of living to which they were introduced through the schools. Learning to read and write, learning to make bricks for building, learning to cook and clean in the missionary's house, being paid in money for work done, buying clothing to wear in school and in church—these were some of the elements in the dominant culture which were acquired through the schools. Professor Sir Frederick Bartlett in his study, *Psychology and Primitive Culture*, has suggested certain lines of research which would establish, among other data, the process of selection by pre-literate peoples of new elements introduced by a foreign culture. This process of selection by the Africans is in one sense the counterpart of the 'intentions' of the Europeans as indicated by Professor Malinowksi in introducing elements from their own culture. Though in one sense the dominant British culture, through the schools, thrust upon the African peoples a wide range of foreign cultural elements, the response to these stimuli, a response which varied in different areas and in different tribal cultures, showed selectiveness in the elements which the African peoples adopted.

The third stage, inevitable as a result of the second, was the rejection by the Africans of certain traditional ideas and former ways of living. Some of these were attacked by the missions as heathen practices; some reflected different types of behaviour in the dominant and traditional cultures. The child was made to stand in front of the European teacher instead of sitting or kneeling in the presence of an elder, and thus his ideas of customary polite behaviour were reversed. The teaching of respect and behaviour through the initiation schools and puberty rites were to a large extent abandoned. As tribal warfare ceased, so did the training of boys in age groups to prepare for military service. Traditional songs, dances and folk-lore were put aside, and hymns, drill, and 'readers' took their place. It is misleading to generalise on this phase, since missionary policy varied about what was permitted and what was not. Also the degree to which traditional practices were completely abandoned or carried on in secret varied from one African tribe to another, and illustrated further the process of selectiveness, in this case in conserving the traditional practices rather than adopting new ones. The general result, however, of this third stage was summed up by an African Paramount Chief, himself a Christian with some schooling, in the words 'the white teachers taught us to despise our past.'

In the fourth stage we see the educational opportunities offered by the dominant culture fully accepted by the Africans. It was characteristic of a phase in which western forms of economic, social and political life were also being rapidly adopted. Leading Africans wanted their children to have a complete 'English' or 'Scottish' education in all its details, fearing that without it their children's development would be retarded, and that they would be discriminated against in

competing with Europeans for professional posts. The chief educational characteristic of this stage was the common yardstick : the taking of British public examinations and the demonstration of African intellectual ability. It was the beginning of measuring up in the intellectual sphere of the people who came from the preliterate traditional culture with the people who came from the dominant culture.

This stage illustrated Professor Bartlett's theme of ' constructiveness ' following selection in cultural change among preliterate peoples. The African peoples had passed through the successive stages of conservatism towards the dominant culture, then selection of elements from it, and then selection of elements to be rejected from their own culture. They were now building into their pattern of living the educational ideas, methods and practices which they had learned from the British. As yet there was little correlation between the traditional culture and this new educational pattern, except in the use of the vernacular languages in the primary schools and even this was not universal.

It was during this stage that doubts began to be expressed by some British educationists in Africa about the curriculum followed in the primary and secondary schools. These doubts arose from two separate sources. One was the need to relate schooling, especially at the primary level in rural areas, to the environment and future occupation of the children. The other, which arose mainly as a result of the work of social anthropologists, was a recognition that there were elements in African traditional culture which should have a place in the educational system, and that it was unsound psychologically and socially to educate children entirely away from their traditional culture. This last point of view found expression in the early planning of life and activities at Achimota. African music, African arts and crafts, African tribal dances had their place in a school whose prestige was high because of the opportunities it offered for advanced education of an English public school type.

The fifth stage illustrates another process of selectiveness by the Africans. By their own choice they had taken the opportunities offered and built a western school system into their social fabric. The common yardstick of public examinations had established their ability to make full use of a western education. They were released from the fear of being held back in educational progress if they turned their attention to studies in their own traditional culture. African educationists began to show an interest in social anthropology, in African linguistics, in African music, and art. The interest in African linguistics was fostered by the scholarships given to Africans to study their own languages in London at the School of Oriental & African Studies, by the papers in African languages offered in the Cambridge School Certificate, and by the creation of Literature Bureaux in several territories for the encouragement and publication of African writing in the vernaculars. The prestige of one or two African artists and musicians in the international world of art and music gave a new impetus to studies in those traditional fields. African teachers began to collect folk tales and traditional games to use in the school curriculum.

This fifth stage marked a partial reinstatement of certain elements in the traditional culture in the educational system. It is significant that those Africans who led the way in this new process of selectiveness had for the most part achieved a high level of educational parity with Europeans. They had gone furthest in the studies in the dominant culture, they had proved their ability to benefit by them, and they were therefore free from the fear of being held back if they looked back to their own past and their own traditional culture.

The sixth stage illustrates a further process of constructiveness, making use of the new selection by Africans of elements in their traditional culture which they wished to incorporate in the educational system. It is a final stage which can be recognised in other countries where a dominant culture has encountered a traditional culture, and in the field of education has been through some, if not all, of the stages we have been considering. In India the *swaraj* or Home Rule movement had its cultural counterpart, where a renewed interest in Indian languages, dress, dancing, art and music took forms which are

well known to the western world. In the West African territories which are now approaching self-government, we can see signs of a cultural *swaraj* movement. The characteristics of this movement are its integration with the political movement, and its appeal to a legendary or mythical past, which is the particular cultural heritage of a tribal people. This form of constructiveness in bringing together elements from the dominant and from the traditional culture has not yet had time to influence the school system nor the curriculum. It has, however, its place in the new University College of the Gold Coast where a Department of African Studies has been set up.

It has not been possible in this short paper to do more than indicate some of the problems in this field of education and cultural contact. Many of them are particularly relevant at the present time, both in the United Kingdom and in British territories overseas. Ideological warfare, which is so characteristic of the present age, makes it imperative to be more aware of these educational problems and to devise adequate means for their solution.

### References


MAIR, L. P. (1934). *An African People in the Twentieth Century*. Routledge.

FEI, H. T. (1939). *Peasant Life in China*. Routledge.

REES, ALWYN D. (1950). *Life in a Welsh Countryside*. University of Wales Press.

REDFIELD, ROBERT (1941). *The Folk Culture of Yucatan*. University of Chicago Press.

MALINOWSKI, BRONISLAW (1945). *The Dynamics of Culture Change*. Yale University Press.

—— (1936). *Native Education and Culture Contact*. International Review of Missions.

SMITH, E. W. (1934). *Indigenous Education in Africa*. In "Essays presented to Professor Seligman." Kegan Paul.

MAYHEW, ARTHUR (1926). *Education of India*. Faber & Gwyer.

H.M.S.O. (1925). *Educational Policy in British Tropical Africa*. Cmd. 2374.

—— (1935). *The Education of African Communities*. Colonial No. 103.

BARTLETT, SIR FREDERICK (1923). *The Psychology of Primitive Culture*. Cambridge University Press.

LINTON, RALPH (1947). *The Cultural Background of Personality*. Kegan Paul.

CLARKE, SIR FRED (1940). *Education and Social Change*. Christian News-Letter Books., No. 3. Sheldon Press, 1940.

# BOTANICAL ASPECTS OF NATURE CONSERVATION IN SCOTLAND[1]

by

PROF. J. R. MATTHEWS

IN dealing with botanical aspects of nature conservation I propose to consider briefly two points of view—the floristic and the vegetational. Together they probably cover most of the intricate and difficult problems which confront those who would seek to conserve the plant-life of Scotland in the broadest sense. The floristic plant geography of the country is relatively well known although Scotland, compared with England, is less well provided with local or county floras, invariably a useful medium for the exposition of a great deal of information which cannot find a place in any general flora. Nevertheless, the Scottish flora has been investigated with at least sufficient thoroughness to permit of a fairly clear discrimination between species which are rare and species which are not rare. There are perfectly good reasons for the conservation of certain species which are common and to these I shall refer later, but for the moment I wish to say something about the rarer species. There are, of course, varying degrees of rarity; a species may be rare because it is highly localised, i.e., restricted to one or a very few localities in the country; or it may be rare in the sense that relatively few individuals of the species occur in the known localities. Not uncommonly the localities are rather widely scattered and the species concerned exhibits a more or less marked discontinuity in distribution. Both kinds of rarity are represented among Scottish plants, especially, though by no means entirely, among members of our mountain flora. *Arabis alpina* occurs only in Skye; *Lychnis alpina* in Clova; *Sagina nivalis* in Breadalbane; *Gentiana nivalis* on Ben Lawers and Caenlochan; and *Astragalus alpinus* on three Scottish mountains.

Scotland received little attention in the way of botanical exploration before the eighteenth century and one of the earliest floras giving an account of our native plants was Lightfoot's *Flora Scotica* published in 1777. In the nineteenth century the explorers were active and many of them, botanists and horticulturists, displayed an apparently irresistible zeal in the acquisition of some of the rarest plants in our flora, both flowering plants and ferns. It may be argued that our Scottish alpines are in little danger of interference because of their remoteness and their more or less inaccessible places of growth, but let me remind you of what a distinguished Edinburgh professor of botany wrote in 1832 about *Gentiana nivalis*, after having gathered it on the precipitous rocks of Caenlochan at the head of Glen Isla. 'The sparkling of this most rare and lovely gem,' he says, 'among the scanty mountain herbage, cured me of hunger and thirst, and made me forget that I was gathering it at the risk of my neck.'

I am well aware that progress in the natural sciences could not have continued without extensive collecting, but when it comes to the rare species in a country the sheer desire for personal possession can be carried too far. Anyone who has turned over the sheets of some of the private herbaria made about the end of the last or beginning of the present century will know exactly what I mean. A single specimen of a rare species seldom sufficed. It is no exaggeration to say that some of our rarest plants have more than once been on the verge of extinction and in some localities, indeed, they seem to have been

[1] Paper read before a joint session of the Sections of Zoology and Botany at Edinburgh on August 10, 1951.

exterminated. I doubt if many specimens of *Lychnis alpina* are to be seen in the old classic locality on the summit of Little Culrannoch where the plant was first discovered by George Don in 1795. And in 1795, little more than 150 years ago, Don must have experienced the great delight of seeing a considerable colony of the plant. It may be true that Scotland has lost few species from its flora in the past century, perhaps only *Lathyrus niger*, *Pinguicula alpina* and *Eriophorum alpinum*, and the loss may be regarded as insignificant. Be that as it may, what of the next 100 years? While I firmly believe there is less unscrupulous and indiscriminate collecting than there used to be, the evil has not been entirely eradicated. There is an obvious need for conservation of many species, be they rare or otherwise, and this involves more than their preservation. As scientists we should recognise in the existence of our mountain flora a fascinating problem or series of problems which are yet far from solved. Each member has had its own vicissitudes and all of them, in one way or another, have shared in the long and varied history of our Scottish flora. The ecological studies which are necessary as contributing to the solution of these problems can be carried out not by preserving the species alone but, what is equally important, by conserving the habitats where they occur. Habitats are never stable for very long, and habitat conservation there must be if some of our rarer plants are to survive. In this connection not only mountain but coastal habitats require careful consideration.

It is but a small step to pass from those species which are rare in the sense of being highly restricted, to those which are less rare but which nevertheless exhibit a narrow ecological amplitude and are becoming rarer as a consequence of man's interference with habitat conditions. These species constitute the waning flora of Scotland. There are several reasons for this, but two main causes have contributed to the decline—drainage and the removal of woodland. I would be the last to minimise the importance of drainage which is in the interest of agriculture and the expansion of agricultural land. Our national economy demands such expansion. Only about 25 per cent. of the land surface of Scotland is cultivated, having been derived in large measure by the reclamation of former marsh and swamp and by the removal of former woodland. Had our forefathers not recognised the importance of drainage, the ploughlands of Scotland would have been less extensive than they are. But the consequences of drainage, together with the natural changes accompanying vegetational succession, are a reduction in the extent of our aquatic and marsh flora and in some areas the disappearance of certain species.

Similar results may follow the drainage of bogs and moorland, though the floristic consequences may be less noticeable because of the much greater extent of these communities when compared with marsh. I can recall clearly the complete disappearance of *Sedum villosum* from one of its few localities on the Ochil Hills by the simple device of opening a channel to drain a small bog into a nearby stream. The area is now under bracken and *Sedum villosum*, *Drosera* and *Pinguicula* have gone. Such interferences with habitat conditions have their inevitable consequence and although the overall effect on the flora of the country may be slight when measured over short periods, the cumulative effect over the centuries may be very great.

As regards woodland I need say little. The story of the exploitation of Scottish forests has been often told and there is no need to relate it in detail. It has been estimated that before man appeared in Scotland about 50 per cent. of the land surface was under forest. At the present time the figure is about 5 per cent. Of native deciduous woodland not much is left and the accompanying flora has diminished accordingly. As some small compensation for this, however, I have been accustomed to regard the familiar hedgerow, often marked by a line of trees, as a relatively secure refuge for many of the more characteristic marginal species of the deciduous woodland. But with changes in land ownership the old hedges are disappearing. The owner-farmer, with perhaps very good reason from his point of view, has been tempted to remove the trees that once marked the boundaries of his fields, and in place of the former open and pleasing parkland we find wide

expanses of arable land ploughed to within a foot or two of the wire fence which has replaced the far more picturesque hedge. I think it is just possible that even the agricultural land of Scotland can be made too tidy, thereby upsetting the balance of nature.

The idea of tidiness has spread also to our roadways. The widening and improvement of roads and the destruction of roadside hedges, while no doubt desirable and necessary in an age of increasing road transport and in an age, too, which worships speed before everything else, have had a marked effect on the marginal flora that could be found along our roadways even thirty or forty years ago. I am particularly concerned about this because, for many years, I made a special study of the rose flora of Scotland and I can state without fear of contradiction that the roses of Scotland are rapidly diminishing. If roads must be widened and dangerous corners removed, would it not be an act of nature conservation and be more in harmony with the native scene to plant bare embankments with wild roses and other wild plants rather than the exotics which are often introduced, which are neither good soil-binders nor beautiful to behold? Again, the modern use of herbicides in the control of 'weeds' on roadside verges will almost certainly produce further changes in an integral part of our country's flora which we cannot afford to lose.

As regards coniferous forest we are left in our own generation with what are perhaps the last remnants of native pinewood. Not only is Scots pine the native and characteristic coniferous tree of the highlands, blending better than any other conifer into the highland scene, it provides also the field conditions which favour a number of distinctive pinewood species. Their names are familiar enough—*Linnaea borealis*, *Moneses uniflora*, *Trientalis europaea*, several species of *Pyrola*, *Corallorhiza trifida*, *Goodyera repens* and *Listera cordata*. Some of these species have become rarer in the present century, due largely to the extensive felling of pine forest during two world wars. *Goodyera repens* disappears almost immediately after felling and *Listera cordata* is particularly sensitive to changes in drainage brought about either during felling or in connection with replanting. If there is an obvious need for conservation it is precisely in connection with those areas which have been denuded of trees. The rarer species of the old pine forest tend to diminish but there is no good reason why this trend should not be checked. A policy of conservation should be possible by collaboration with the Forestry Commission and other owners of woodland, and I am reasonably confident and, indeed, there is evidence that some of our pinewood species will spread into the new plantations which are being formed.

I have spoken of some of the floristic aspects of conservation and the need for the conservation of individual species. They are all, of course, constituents of particular communities of plants, and it is probably true to say that in the past the enormous reduction in woodland and the drainage of marshes and fens have brought about the most conspicuous changes in the distribution of our flora as a whole. For out of the wooded and marshy lowlands and from the lower valley slopes has come most of the agricultural land of Scotland, while on the uplands and more mountainous regions heather and moorland and hill grazings have expanded, again in many areas at the expense of former woodland.

From the floristic point of view the composition of heath, moorland and hill pasture is liable to strike the botanical collector as a trifle dull and monotonous. The wide expanses of these communities, which cover more than 65 per cent. of the surface of Scotland, do not provide the variety of species to be found on some of the higher summits with their more varied flora of corries, crags and ledges. Over much of the hill country above the zone of cultivation one or a few species may be dominant. Among the most widespread of upland plant communities is so-called siliceous grassland comprising mainly bent and fescue. Under different habitat conditions the prevailing species may be *Nardus* or Mat grass, and elsewhere *Molinia*, Purple Moor-grass, may gain dominance, while over very extensive areas bracken has spread and continues to spread. These rough grazings, including various types of bog and moorland, cover

11 to 12 million acres of hill land—more than half of the total area of Scotland. It is an enormous expanse of undeveloped and underdeveloped land, but because of remoteness and inaccessibility and because of soil infertility, shallowness of soil, problems of drainage and other difficulties it becomes necessary to take a realistic view and recognise that no more than a small fraction can ever be profitably developed. Nevertheless, the demand for increased food production has focused attention on these rough grazings and indeed the problem is but part of the wider and more general problem of the Highlands.

The question may well be asked, therefore, whether there is any need for the conservation of large areas of semi-natural and natural vegetation of hill land and to the question different answers are likely to be given. There are some who would leave conditions as they are. Others urge the greater economic use of our upland pastures and moorlands, both for agricultural and afforestation purposes. I see no reason why conservation and economic development should not operate together. If all the factors were known, the latter might well become dependent upon the former. But we are not certain of all the factors which have operated in the past and which have brought about the conditions of the present. We can, however, be reasonably certain that present conditions will not persist indefinitely, since vegetation is never static and man can hasten the changes in one direction or another. To a large extent the present vegetation of the hills is what man has made it. In the first place, therefore, it would be well to know, far more accurately than we do, the extent of the varying vegetation resources of the hills and the moors. These resources, except for small areas, have not yet been surveyed in sufficient detail. We have, in fact, no complete and accurate survey of the vegetation of Scotland—to my mind a prerequisite to any plan for conservation or development. A good deal is now known about the nutritive value to the grazing animal of different grasses and different kinds of moorland species, but we require to know far more exactly than we do the distribution of the several species concerned. Their number is not large but they are the common and abundant species and frequently they are the characteristic dominants over large areas. I should be surprised, however, if from existing knowledge it were possible to produce a map of Scotland showing with anything approaching exactitude the areas dominated by Sheep's fescue, Bent-grass, Mat grass, Purple Moor-grass, Heather, Bilberry, Deer grass, Cotton grass, the Common Rush, the jointed Rush or Bracken—less than a dozen species but all of them significant. These plants form a very large proportion of the botanical raw material with which both the forester and the hill farmer have to deal. If conservation and development are to proceed along scientific lines a comprehensive survey of the hill lands of Scotland is a primary need. The time is appropriate now, when the soil survey of Scotland is in active progress. No more favourable opportunity will occur for obtaining a valuable record of upland vegetation in relation to soils and varying soil fertility. If it is true that the deterioration of many hill grazings is due to leaching it should be possible, as indeed it is possible, to determine the deficiencies and equally possible to reverse the process. While it is important in the interest of botanical science to protect and conserve the 70 or 80 rare species of plants in Scotland, it is equally important from the point of view of economic development and increased productivity to investigate critically ten or a dozen of the commonest species comprising our hill grazings, conserve what can be shown to be of value and improve the less valuable. It is true that this has already been done up to a point. Heather-clad areas, bracken-infested ground and poor hill grassland have been replaced by pastures that are more productive. But the areas involved in many cases are little more than experimental and the methods of improvement have yet to be applied on a much larger scale. You may regard this as agricultural development as, of course, it is ; but it is also very much concerned with the conservation of the botanical resources of our country.

Reference must be made also to the peat deposits which underlie the present

vegetation of peat mosses or peat bogs. The peat is of variable depth but if only those deposits which have a minimum depth of 2 feet are taken into account, it is estimated that the total area of such deposits is of the order of 2 million acres, by far the greatest extent occurring in the Highlands, the Outer Hebrides and the Orkney and Shetland Islands. The peat mosses of the Midland Valley are estimated to cover about 150,000 acres, the larger ones being Aird's Moss and Flanders Moss, each about 3,000 acres. The need for the conservation of peat and the various types of vegetation which give rise to it may well require careful consideration if the existing peat mosses are to be subjected to commercial exploitation on any large scale. Considerable attention was given to the possible uses of peat during the war and a preliminary account was published in 1943. The economic possibilities are still being explored and detailed surveys are now in progress in order to obtain accurate information about the peat deposits of Scotland. According to a recent estimate there are about 10,000 square miles of workable peat in the country; an estimated 400 million tons of fuel, enough to keep the existing electricity stations in Scotland going for 250 years.

Early this year it was announced that Ireland had planned to dig 4,000,000 tons of peat in 1951. If Scotland follows Ireland's example it will not be easy for the biologist, concerned with any long-term policy for the conservation of nature, to view such a scheme with equanimity or complacency. Of all soils peat is one of the most retentive of water and any extensive removal of the protective covering of peat and peat vegetation might bring serious consequences particularly in regions of high rainfall, itself an important factor in peat formation.

It should be clear that any future development of land involving its native vegetation must be viewed in the light of a considered policy of plant conservation. No botanist can have any desire to see a further diminishing of our rarer species, for they are of special interest and importance to the scientist. Nor is it desirable, botanically or economically, to do nothing to modify the trends of soil exhaustion which lead to decreased productivity of large areas of hill pastures. The best of these should be conserved even from the botanical aspect alone since they have a richer and more varied flora than the poorer rough grazings. Some of these can, however, be upgraded and in so doing agriculture and afforestation can share. But in attaining a forest climax of vegetation on hill country and so restoring something which has been lost, I would like to see a far more extensive restoration of our native pine.

To the botanist, therefore, there are two main sets of problems which cannot be entirely separated since they are interrelated and interdependent. There are the ecological problems centring round species and ecological problems concerning communities of species. We have to think both of flora and of vegetation. If both are to be conserved research into the methods of conservation is needed. We know a good deal already but the complex relationships of any biotic community, which must include the effects brought about by man, require further study and analysis.

To this end the Nature Conservancy has been established. Its functions are summarised in its Charter: 'To provide scientific advice on the conservation and control of the natural flora and fauna of Great Britain; to establish, maintain and manage nature reserves in Great Britain, including the maintenance of physical features of scientific interest; and to organise and develop the research and scientific services related thereto.' One word more: there is nothing in this antagonistic to the interests of Agriculture or Forestry. On the contrary, the scientific work of the Conservancy which will become possible in the proposed nature reserves will not only add to fundamental knowledge but will also contribute to the advantageous development of much of the land surface of Scotland.

# ETHOLOGY COMES OF AGE[1]

by

PROF. R. J. PUMPHREY, F.R.S.

*Ethology* is a word of respectable antiquity and in its dictionary meaning, *the study of customs*, it constituted, I suppose, a considerable part of social anthropology. But recently some wise and far-sighted person has applied it quite legitimately to the study of all animal behaviour including that of man. In this sense it seems to be catching on : and it is in this sense that it is used here.

A word with this wide meaning was badly needed. Science is held up for lack of the right word or by choice of the wrong one more often and more seriously than scientists care to admit. It is a happy omen that a word has been found which has the right sort of feel and which is neither an unintelligible barbarism (like the word *behaviour* which it took three centuries to civilise) nor a debased coin, sticky with deplorable and paralysing associations. It is a happy omen because it reflects the fact that the subject which Ethology describes is growing up into some sort of unity. And it is important and urgent that it should—far more important than any of the physical and chemical technology into which most of our effort and brains and money are going.

The late Michael Roberts, in his posthumously published book, *The Estate of Man*, wrote : 'The world has enough oil to last 22 years, enough coal to last 500 years and enough damsilliness to last for ever.' It is, I think, an unduly pessimistic estimate, but it does point in the right direction. A catastrophe is foreseeable which cannot be avoided by petrol substitutes or by subsidies for agriculture, by the welfare state or by making the Sahara blossom like a rose. These are palliatives which by themselves will fail even to palliate, for the rise in world population, the desire of nearly everyone for a higher standard of living than his neighbour, and the continuance of international suspicion will ensure that any marginal surplus is absorbed or wasted and that any conceivable increase in essential productivity is overtaken from the start. The only hope for humanity lies in a resolute attack on damsilliness ; it is by no means a forlorn hope ; and it is for ethologists to undertake it.

Some work recently published gives an indication of where the attack might start. It is not, however, my intention here to speculate about the future strategy of the campaign, but rather to cast a retrospective eye over the past. Why was Ethology not born until 1872 ? And why, having arrived in that year an apparently healthy though nameless infant, was its development arrested so that it is only now approaching the beginning of its effective working life ? In searching for the answer to these questions, we can, I believe, find some encouragement for the future and a salutary lesson in the unwisdom of tripping ourselves up with words and of building, out of prejudice and cliché and tabu, apparently insuperable obstacles to progress.

In the long run, progress in science can properly be regarded as a succession of victories over obstacles to the free-will in which, in practice, we all believe because any other hypothesis leads to absurdity. We are all so imbued with the body-mind dualism of Descartes that it is difficult to avoid classifying the obstacles to free will as material and mental. And if we do so, it appears at first sight as if the victories of mankind had been over the material limitations to the exclusion of the mental. By material limitations we generally mean things of this kind : that unassisted by extraneous machinery we cannot fly or even run a mile in less than four minutes

[1] Paper read before a joint Session of the Sections of Zoology and Psychology at Edinburgh on August 13, 1951.

or feed or clothe ourselves, or understand speech at a distance of more than a few score yards or swim very far, or see through brick walls, and so on. All these and endless other limitations of a material kind have been overcome or evaded within the last hundred thousand years by inventions ranging from ancient devices like the spear and the bow, the needle and the net, the pot and the plough and the boat, to modern systems of production, transport, communication.

By comparison it would seem that the attack on mental limitations has failed or not been seriously attempted. We are still driven, once our bellies have been filled, to pursue ends which fantasy paints in glowing colours but which are unattainable in practice or turn to dust and ashes when they are attained. Damsilliness seems to stand very much where it did. Man is still only to a very slight degree a rational animal and there is no evidence that he is genotypically more intelligent than his palaeolithic ancestors.

There is, however, one aspect of mental activity where his victory has been decisive. His individual memory is fallible and limited by his individual life-span ; but the successive inventions of speech about 50,000 years ago, of writing rather more than 5,000 years ago and of printing rather less than 500 years ago have progressively reduced these limitations to the point where no discovery which is expressible in words need be lost. This series of inventions is obviously primary in the sense that all or nearly all the other victories over material limitations are consequential ; but the qualification *expressible in words* is important, because, though it is obvious that gifted individuals have from time to time achieved substantial victory over their own mental limitations, the descriptions which they have left of their tactics have always proved to be susceptible of alternative interpretations, or self-contradictory, or in some cases simply unintelligible.

The business of scientists in quite general terms is to search for and find, in the stored data of human experience, regularities by which the data can be reduced to an ordered and self-consistent system into which new data can confidently be expected to fit. A scientist in fact is one who believes that the universe works according to rules which man can understand and that, by understanding, and only so, can he rely on bending the future to his purposes. We are all scientists to some extent, none of us are completely so. And the same is true of our earliest human ancestors. The commonly accepted view that we live in an age of science, which our ancestors got along very well without, is unhistorical. Science is at least as old as speech and it is quite evident that it was by discovering rules about mechanics and ballistics, the properties of matter, the strength of materials and the transfer of heat, that man very early systematised the production of clothing and of a wide variety of tools and technical appliances.

We must suppose that he was always equally interested in finding the rules governing the behaviour of his fellows and of those animals and plants which fed and clothed him. Unfortunately these rules, apart from those imposed by diurnal and seasonal periodicities, are much more difficult to detect than the rules applicable to inanimate objects. Magic is nothing more than science with the wrong rules, and it tends to persist, because in any field where the data are sufficiently complex for the wrong rules to be assumed in the first place, the same complexity makes them difficult to disprove. There is good evidence that Upper Palaeolithic man was practising magic about other animals and other men at the same time that he was making great advances in the science and technology of inanimate things. But we need not feel superior on that account, for the magical element is still only too obvious in the sociology and politics and economics of to-day and is only just being dislodged from medicine and agriculture.

There is therefore very good reason why what we now call Ethology should have been till recently almost exclusively magical and unprogressive and fragmentary. Some catalyst was needed before we could begin to discard the wrong rules and consolidate it into a self-consistent and unitary system. Such a catalyst was the hypothesis of evolution. With the publication of the *Origin of Species* and the subsequent widespread acceptance of evolution as a fact of history rather than as

an intriguing intellectual toy, the way seemed open for a constructive Ethology. Darwin knew it and in his *Expression of the Emotions in Man and Animals* laid the foundation stone in 1872. And then nothing much seemed to happen. Why? I am afraid that the psychologists were partly to blame. Instead of accepting evolution as a fact and examining the behaviour of other animals in order to relay the foundations of human psychology, they followed the fashion set by Herbert Spencer, accepted as fact their current pre-conceptions about Man, and did a little slumming among the animals with the express intention of finding more evidence for evolution. And it was not to the behaviour of real animals that they turned but to the largely apocryphal literature about animal behaviour, with results so lamentable that 'Anthropomorphist' became a term of abuse and is still one of the most effective blunt instruments in the vocabulary of scientific polemics. Yet, even if we do not accept without qualification Darwin's explicit belief that the instincts, emotions and intelligence of animals do not differ in kind from our own, however greatly they may differ in degree, it is surely evident that an anthropomorphic outlook is justified if evolution is fully accepted as a fact.

The zoologists also fought shy of the central question but in a quite different way. Their counter to critics of evolutionary doctrine lay in the pursuit of a ruthless objectivity, and since it is much easier to be ruthlessly objective about a dead animal than a living one, zoology tended to concern itself more and more with states and the minutiae of structure and less and less with processes and functions and behaviour.

This retreat from reality by zoologists and by psychologists alike, though in different directions, had a number of important consequences, which looking back after a safe interval, we can now begin to recognise and disentangle. Dr. Pantin has drawn attention to some of them in his Presidential address (*Advancement of Science*, **30**, 138). Zoologists became infatuated with the belief that if only they were sufficiently objective, the processes of living, from which they sedulously averted their eyes, would somehow become explicable in terms of physics and chemistry. Because the teleological argument had been quite illegitimately pinched and incorporated in the armoury of the opponents of evolution, teleology was regarded by zoologists with distrust and aversion. Even to-day when the accurate and proper use of language has entrapped a zoologist into a statement which seems to him heretical, it is quite usual to hear him apologise for speaking teleologically; and he generally looks as sheepish and embarrassed about it as if his bedroom had been found full of empty whisky bottles.

Yet teleology is no more than the implication of purpose. If we ask the question, What is this for? or the exactly equivalent question, What is its function? we are asking teleological questions to which the only intelligible answers are teleological. Physiology is evidently a teleological subject—so entirely so, that the propriety of speaking teleologically has in this field never been seriously raised.

The zoologists, however, frightened themselves silly with a bogy of their own creation, and succeeded also in frightening the exponents of the new comparative psychology which was growing up principally in the United States. The originators of this school seemed to have been actuated partly by a reaction against body-mind dualism, inherited from Descartes and firmly entrenched in classical psychology, partly by hopeful admiration of the alleged objectivity of physicists and chemists, and partly by fear of the turnip-head of teleology. They were, as we are, the slaves as well as the makers of the current fashion in thought. Only so can we account for the combination which they displayed of virtuosity in technique with what appears in retrospect an almost incredible obtuseness in the interpretation of results. From experiments beautifully designed to exclude every form of behaviour but one, the conclusion was drawn that no other type of behaviour was observable. Although, to any honest observer who looked at animals while they were still alive, the goal-seeking character of their behaviour was its most obvious characteristic—indeed the whole technical apparatus of comparative psychology

was founded on reward and punishment—yet the implications of teleology were evaded by a piece of sophistry so transparent that it is difficult now to see how it can ever have seemed convincing. Stripped to essentials the argument runs as follows:—

1. Machines can be made to behave like animals.
2. Machines are not conscious and are insusceptible of reward or punishment.
3. Therefore machines are not purposive in their activities.
4. Therefore the attribution of purpose to the activities of animals is redundant and condemned by the law of parsimony.

It would be tedious and at this date superfluous to pick this monstrous argument to pieces but it is worth noticing that, though it was attacked at the time, the attack was directed rather to the inadequacy of the imitation of animals by machines than to the contradiction in the assertion that machines are not purposive. For that of course is just what they are. By universal custom in all western languages since its archetype projected the god on to the stage, a machine is and has always been a contraption *for* doing something. A machine which was not designed and was incapable of fulfilling a purpose is inconceivable. There can be no such thing as a machine *sui generis* existing independently of a constructor and user. Machines are made to fulfil animal ends and there is nothing surprising in the fact that their behaviour frequently presents an analogy with the behaviour of animals. But it is not a fruitful analogy—this ghost of the long-defunct mechanistic theory. The comparison of eyes with cameras, of brains with calculating machines, of proprioceptively-adjusted muscular systems with servo-mechanisms is empty, since a study of the machine can tell us nothing about the behaviour of the living system on which it is modelled which we did not already know before we made it.

Yet despite the current popularity of the mechanical analogy, I believe that ethology is becoming scientific. We are beginning to realise that its rules are to be sought and can only be found in the data of behaviour ; and that the *a priori* assumption of a mechanical or a physico-chemical or a physiological aetiology is just as magical as the assumption that an enemy can be injured by sticking pins into his image.

Ethology is becoming scientific but it is not yet unified, because there is still a perceptible cleavage between animal and human ethology. Evolution has been accepted intellectually but with a conscious or subconscious reservation traceable directly to Descartes. His assertion that men were singularities, in a Universe in which all other living things were machines designed by God to fulfil His purposes, was so flattering to human vanity and so convenient that it was instantly accepted as axiomatic. So, despite Darwin, many people even to-day, who assent intellectually to Evolution, do not really believe that they behave in accordance with rules which govern the behaviour of a monkey or a cockroach. The resulting mental conflict has led to a persistent disregard of evidence inconsistent with a dualistic ethology and to a language and terminology designed to conceal this inconsistency from the users of it. These languages—for there are many versions—are regarded by their authors as being the language of objective description, and as excluding the errors of subjectivism and anthropomorphism. Thus man can see but animals are photoreceptive. Man remembers but we must not say that the elephant never forgets. To be objective we must say that elephants seem to behave as if they were subject to a persistent mnemic histeresis resembling the behaviour of steel in an inconstant magnetic field. Man is capable of loyalty but a dog is conditioned by the association of his master's approbation with food. Man reasons from experience, animals learn by trial and error. Man is swayed by emotions, animals by ' action specific energy,' and so on endlessly.

Most of the attempts at objectivity seem on examination to be roundabout ways of saying something which, if it had been expressed in everyday language, would immediately be recognised as a falsehood or a platitude or an irrelevancy. Watson's triumphant generalisation that all overt behaviour is reducible to a simple causal

relation between stimulus and response is an example of the type of objectivist statement which is false or trite according to the meaning attaching to the words *stimulus* and *response*—a meaning which Watson himself never attempted to clarify.

Watson's book, however, is over 30 years old. I think we have now reached a time at which both the divergence in the languages of human and animal ethology and the underlying dualistic reservation in favour of man's ethological uniqueness can be abandoned. And with the explicit acceptance of the basic similarity of the behaviour of man and other animals in its goal-seeking character the way will be open for an attack on what seems to me the central problem of ethology—the nature and rules of motivation and valuation. The profit motive is indestructible in men and animals except by death, but the notion of what constitutes profit—the nature of the immediate or the remote goal changes in apparently arbitrary manner from time to time, and from individual to individual. It is obvious that many of the ends which individual men consciously pursue are symbolic substitutes for something else, and that the damsilliness of the human race is intimately connected with the inadequacy or impropriety or antisocial character of many of these symbols, and with our massive ignorance of the rules governing the substitution. It is here, I believe, that the integration of human and animal ethology is likely to be most productive. Lorenz's work on substitute activities in birds, E. S. Russell's work on equivalent symbols, von Frisch's analysis of the symbolic language of bees are all extremely pertinent to human behaviour.

Semantics, the science of symbols, has remained an almost pathless wilderness because its roots in our animal ancestry have been ignored. *Now* it looks as if it will be possible to establish it on a rational basis. And, as I have tried to emphasise, the difficulties attending any scientific advance are both technical and linguistic. In ethology semantics is doubly implicated, in the technique, and in the interpretation of results and their reduction to intelligible rules.

Ethologists are sensibly abandoning the attempt at an objectivity which conceals a belief that a complete aetiology of animal behaviour is extractible from the so-called exact sciences. The way now lies open. It is not for the physicist to explain ethology. Ultimately it will be for the ethogist to explain the physicist, the ethologist and the man in the street to themselves.

# SOCIAL SERVICES EXPENDITURE DURING THE LAST 100 YEARS[1]

by

J. STIRLING

1. *Apology*

It was with some diffidence and misgiving that I undertook to prepare this paper. The task would have been much better entrusted to a serious student of social and economic history, than to an accountant; for, although I have spent the greater part of my working lifetime in a Social Service Department, I feel I have been too busy counting the trees in our little corner of the forest to have been able to survey it properly, let alone measure its growth over the last century. If therefore my paper falls somewhat short of the standard which the Association has the right to expect, please put this down to the limitations of my training and deal with me charitably!

2. *Scope of Paper*

The scope of the Paper is indicated in the tabular statement in the Appendix. It is the same as that of the public social service returns from which most of my material is obtained, with the exception that war pensions are dropped as representing abnormal expenditure which is out of place in a historical survey.

3. *Sources of Information*

The main sources of information are listed at the end. In the Paper as originally prepared I commented in some detail on the origin and history of the Social Services Return but have now had to omit these notes.

4. *Method of Presentation*

Please refer to the Appendix, while I try to explain what I have attempted to do and why, and the assumptions on which some of my figures are based.

[1] Paper read before the Economics Section at Edinburgh on August 14, 1951.

First of all there are one or two general points I should like to make:

(*a*) Capital expenditure, wherever identifiable, has been excluded, because the relative loan charges should form an element in the annual expenditure.

(*b*) Owing to difficulties which I shall explain later I found it necessary to make the statement cover the whole of the old United Kingdom up to and including the 1910–11 column and Great Britain only, from and including the 1920–21 column.

(*c*) As already stated only publicly-borne expenditure is dealt with, i.e. expenditure borne on the Exchequer or on the local authorities' rates; so that in connection, for example, with the contributory insurance schemes the employers' and employees' contributions are ignored; for the Education Service school fees are ignored; for the Housing Services the rents are ignored. Not only so, but I have been obliged to lump Exchequer-borne and rate-borne expenditure together. This is mainly because in the last year—the most important year of all—this is done in the return on which I was dependent for my figures. But there is another reason. Throughout the greater part of the century the so-called rate-borne expenditure was not wholly rate-borne at all. From the sixties or seventies of last century up to 1928, local authorities received from the Government, grants in aid to supplement their local rates, representing a diversion of certain elements of Imperial revenue such as additional beer and spirit duties and licences, gun, dog and carriage licences, and a proportion of the death duties—all of which passed through the 'local taxation account'; from 1929 until the coming into operation of the Local Government Act of 1948 this was replaced by the

General Exchequer Grant, otherwise known as the ' block grant ' based mainly on weighted population ; and since then by Equalisation Grant based principally on relative rating resources. But as these grants in aid were not as a rule related to the cost of any specific services it would not be possible, except by dissecting the expenditure of every local authority in the country, to arrive at the true cost of the Social Services to the Exchequer and to the rates respectively.

There is still another complication affecting the sources from which the gross expenditure on the Social Services is met ; contributions under the National Insurance schemes, which have latterly become quite a substantial charge on employers and employees alike, do not wholly represent ' non-public ' expenditure. Employees receive an income tax allowance in respect of the pensions element in their contributions, while the whole of the employers' contributions are brought to account in their profit and loss accounts for income tax purposes as expenses analogous to the salaries and wages to which they are related. Indirectly therefore, by the remission of income tax the Government are again making a contribution towards the gross cost of these Social Services, quite apart from their direct contributions in the shape of *ad hoc* grants and their indirect contributions through the Equalisation Grant.

(*d*) Figures have been extracted at twenty-year intervals from 1850–51 to 1890–91 when Social Services as we now know them were virtually non-existent ; at ten-yearly intervals from 1890–91 to 1920–21 when the pace began to quicken ; and at five-yearly intervals from 1920–21 when developments became more rapid, up to 1947–48—the last complete financial year before the advent of the new National Insurance, Health, and Assistance Services—with the omission of 1940–41 and 1945–46 when the full returns were not available and when in any case the figures would almost certainly be distorted by war conditions ; and finally for 1949–50, the first complete financial year after these revolutionary changes.

Please now consider the various items in respect of which comparative statistics are offered :—

*Item 1.*

For Item 1 of the Table—the broad analysis of the approximate actual or the estimated expenditure on the Social Services over the period—I have taken the figures for 1949–50 from the latest return in the May 1951 Digest of Statistics, grouping the items to correspond as closely as possible to the equivalent items in the earlier returns. For 1947–48 the figures have been taken from the abridged Social Services Return published in Hansard ; this did not give the break-up between public and non-public expenditure, but as this was rather a vital year my colleagues in the Departments concerned have been good enough to supply me with the information they would have submitted to the Treasury for the full return. For the years 1920–21 to 1935–36 the figures are taken from the returns as published, with the addition against Widows, Orphans and Old Age Pensions, of the Exchequer contributions paid into the Treasury Pensions Account to enable that Account to feed the Departmental Pensions Accounts against which the pensions paid are charged. As regards 1910–11 it was fortunate that a break-up of the sources from which the expenditure for that year was met, was given in the 1925–26 return for comparison, so that I have been able to quote for that year the actual, or at least the approximate, amount of publicly-borne as distinct from gross expenditure. I did not have this information for 1900–01 or 1890–91 but, assuming that conditions had not changed greatly over the period, I constructed it by applying to the gross expenditure in the columns for those years the ratio which for 1910–11 the publicly-borne expenditure bore to the gross expenditure. For the two biggest items—education and relief of the poor—the ratio is 95 per cent. ; and the overall ratio is 92 per cent. ; so that the margin of error cannot be appreciable. For the years 1850–51 and 1870–71 I had to fall back on the old statistical abstracts held by the Treasury, but first took the precaution of making a broad reconciliation in total between the corresponding figures for 1890–91 and the figures appearing in the return. I say ' in total ' because in the return there have been transfers from relief of the poor to hospitals

and lunacy ; we will discuss that point later on in dealing with developments in the Social Services.

I should say that all Social Service returns, except that for 1920–21, cover only Great Britain ; it was for that reason that I had to exclude the figures for Ireland in the 1920–21 return and work generally on a Great Britain basis from 1920–21 onwards. Finally, I should point out that I have quoted the proportion which the publicly-borne expenditure incurred under each head bears to the total, bringing out the varying preponderence of the various services at different stages throughout the century.

*Item 2.*

Turn now to Item 2—the estimated national income at current prices. For 1870–71 to 1935–36 the figures are taken from the Table in Mr. Prest's paper published in the 'Economic Journal' ; for 1947–48 and 1949–50 they are taken from the latest Statistical Abstract. 1850–51 presented some difficulty, and finally, after an unsuccessful search for more reliable data, I extracted from the Statistical Abstracts the income of all types brought to assessment for income tax in the years 1850–51 and 1870–71 respectively and I applied the 1850–51 to 1870–1871 ratio to the estimate of the 1870–71 Income. The result looks quite reasonable because while it shows that the national income appears to have increased by fully 50 per cent. between 1850–51 and 1870–71, this corresponds to the ratio of increase during the following twenty-year period ; and everyone knows there was a substantial and growing industrial and commercial expansion over that whole period of 40 years.

For consistency with the statement of expenditure, the estimates of national income are for the old United Kingdom up to 1910–11 and for Great Britain only from 1920–21 onwards—the latter figures having been arrived at by discounting for Northern Ireland on the basis of population. The underlying assumption of a fairly uniform rate of income per head is not unreasonable, as both Northern Ireland and Great Britain have a mixed industrial, commercial, and agricultural economy. If it had been possible I would have reduced the whole statement to a Great Britain basis throughout, but this would have meant discounting for all Ireland in the earlier years. Here one could not possibly assume that the Ireland of last century with its predominantly peasant economy had anything like the same rate of income per head of population as Great Britain. I could not obtain any comparative statistics bearing on the problem and I was not prepared to guess that the Irish level was 33⅓ per cent., 50 per cent. or any other proportion of the British level. In 1850–51 the population of Ireland was 6·6 million compared with 20·8 million for Great Britain and in 1870–71 5·8 million compared with 23·1 million, so you will appreciate that any bad guessing here would have seriously vitiated the figures ; and you will probably agree that I was right to stick to the United Kingdom for the earlier period.

*Item 3.*

From the first two items we arrive at Item 3—the ratio which the publicly-borne expenditure on the Social Services has borne to the total national income over the period. The crude figures of expenditure could, of course, have been equated to a standard price level but I thought this alternative gave a better picture, for not only does it cancel out the variations in price levels but it serves in a rough sort of way to measure in terms of proportionate public cash commitments the growth of the social conscience of the nation—its growing realisation of the necessity for communal provision against the ills of life such as sickness and unemployment, which are suffered by families who cannot face them from their own resources, and might therefore become paupers through no fault of their own.

*Item 4.*

At 4 I have quoted the population on the same basis as the national income and the Social Services expenditure, viz. the old United Kingdom up to 1910–11 and Great Britain only from 1920–21.

*Item 5.*

This enables the position to be regarded from another angle at 5, viz. the relative expenditure per head of population. By

itself, however, this is not very informative since any reliable comparison is completely obscured by the enormous increases in price levels over the century.

*Item 6.*

At 6 accordingly I quote a comparative price index based very appropriately on 1900–01 as the standard year—the mid point of the century and the eve of the beginning of the developments of the Social Services as we now know them. For the years 1870–71 to 1935–36 the figures are taken from the Table in Mr. Prest's paper ; for 1947–48 and 1949–50 from the Statistical Abstracts ; and for 1850–51 the figure is taken from a graph in the L. G. B. Blue book which begins in that year and overlaps the earlier part of the period covered by Mr. Prest.

*Item 7.*

This leads up to 7—the expenditure per head of population equated to the 1900 price level—giving perhaps the best idea of the trend over the century.

*Items 8–10.*

For good measure, however, I have also given at 8 the average income per head of population at current prices, at 9 the same equated to the 1900 price level, and at 10 the amount per £1 of the average income diverted to meet public expenditure on Social Services. The last, of course, represents just the ratios at Item 2 applied to £1. But it gave me a back-check on my later calculations and may look a little more interesting.

I am sorry to have taken up so much time in this preamble but I wished to avoid any illusions as to the sources of my figures, the basis on which I have worked them up, or the assumptions on which I have worked ; and if fallacies are seen in any of these assumptions, the value of the table and the paper will have to be discounted accordingly.

We can now go on to consider the figures themselves and the more significant developments in Social Services of which they are the result.

5. and 6. 1850–51 *and* 1870–71

Again because of my time limit I find I must greatly condense what I had proposed to say about 1850–51 and 1870–71. The intervening period of twenty years saw very substantial developments in environmental health services following the cholera scares of the thirties and forties. But apart from a little public expenditure on education, principally grants to voluntary schools, there were no social services provided at public expense except those available under the Poor Law and a family had to become completely destitute before they could qualify for these. Otherwise persons requiring help had to rely on private and organised charity and on mutual help, for already the friendly society movement was strongly developed. Practically the whole burden of public expenditure fell on local authority rates supplemented only by their receipts from the Local Taxation Account.

7. 1890–91

Again I have had to cut down the material I had prepared about 1890–91 and the preceding twenty years.

Generally speaking the range of public expenditure up to 1890 had not greatly changed ; although with the publication in 1919 of the first Social Services Return quoting comparative figures for 1890, some expenditure which would otherwise have continued to be shown under Poor Relief is now shown under hospitals and lunacy while, for the first time, some negligible expenditure on housing can be identified.

There has been a substantial increase in public expenditure on education due to the passing of the Education Act of 1870, which for the first time made provision for a universal system of public elementary education.

The rate of public expenditure per £1 of national income had risen to 4*d.*

8. 1900–01

The range of expenditure is still the same, but there was a steady rise under all the heads shown. This must have been due generally to expansion in the services provided and further improvements in the standards of these services, and increases in salaries and wages of the staff employed —a continuation of the trend observed in dealing with the 1890–91 figures. This must be so in the case of poor relief,

for the numbers of indoor and outdoor paupers are approximately the same as in 1890–91; as regards education the increase will also be due to the full effect of the introduction of universal free elementary education and the growing development of secondary education.

This year marks the end of the old century and also virtually the end of the old 'laissez-faire' regime in which Social Services and the relief of pauperism had in theory been virtually synonymous (except from 1870 in the field of education) —although as we have seen in practice this principle had already been undermined by the expansion of services provided under Poor Law auspices to persons other than paupers.

In general, over the period, the actual public expenditure on Social Services increased five-fold against the three-fold increase in the national income and the appropriation per £1 of national income rose from 2¾*d.* in 1850–51 to 5*d.* in 1900–01—an increase of about 82 per cent.

Other features of the period just reviewed were that private contributions towards the cost of the services provided were negligible and that—again with the exception of the educational services which were heavily grant-aided from the Exchequer—practically all the publicly-borne expenditure fell on the local authority rates (supplemented, however, as I have already pointed out, by Exchequer grant-in-aid through the Local Taxation Account). In both these respects, as we shall see, the position changes materially in the years still to be reviewed.

9. 1910–11

During the first decade of this century things were beginning to stir. The extent of physical deterioration in the industrial population revealed by the wholesale rejection of volunteers for the forces during the South African war had alarmed the country and the Government, and had given rise to demands for reforms from many quarters. The direct consequence was the introduction of legislation in 1906 permitting Education Authorities in England and Wales to provide meals for necessitous school children and in 1907 requiring them to provide medical inspection for schoolchildren—followed in 1908 by similar provisions in Scotland. These, of course, were services attracting Exchequer grant.

Another break with the past occurred in 1908 with the passing of the first non-contributory Old Age Pensions Act, conferring pensions (5*s.* per week) on persons of 70 or over, subject to a not very stringent means test. The cost of this effort to keep the aged poor out of the workhouse and off poor relief amounted in 1910–11 to £7·4m. This fell entirely on the Exchequer; and to the extent to which it achieved its purpose it represents a transfer of burden from the rates to the Exchequer.

Meanwhile the cost of education was rising owing to the rapid development of the service, particularly now on the secondary and technical sides. So also was the cost of poor relief; the reason for this was not any increase in the numbers provided for but must have been continued rising costs. I cannot quote any reasons more specific than those already mentioned, but I can produce collateral evidence from the L. G. B. Blue book which reports that between 1856–57 and 1906–07 in England and Wales the cost, per pauper, of in-relief rose from £16 12*s.* per annum to £29 5*s.* per annum, and of outdoor relief from £4 13*s.* per annum to £7 1*s.* per annum; the total expenditure accounted for in these years was £5·5m and £11·6m respectively, the increase being ascribed to those rising costs and to the increase in indoor pauperism. Compare these figures with those shown in the table for 1850–51 and 1910–11 respectively.

The small but increasing volume of housing expenditure is still wholly local authority expenditure attributable to the operations of the more progressive authorities in the clearance of insanitary areas and rehousing of families displaced, under powers conferred on them by the Housing of the Working Classes Act of 1890. The expenditure quoted, of course, is net, after taking into account rents received from the authorites' tenants.

In 1910–11 the public expenditure on Social Services had crept up to about 7*d.* per £1 of the national income.

10. 1920–21

The length of the gap here is unfortunate for it covers nine years following the introduction of the first National Health Insurance and Unemployment Insurance Schemes before the 1914–18 war, including the war period itself with the inflation which accompanied and followed it. I should like to have been able to produce comparative figures for 1913–14 to show generally how far Social Services expenditure had developed and in particular the effect of the introduction of the National Insurance Schemes, before comparison of the actual volume of expenditure with earlier years was vitiated by wartime and post-war inflation. But the Social Services returns do not cover 1913–14 and it would have been impossible for me to extract the figures from their many original sources.

For 1920–21 and onwards, also, we switch from a United Kingdom to a Great Britain basis because the Social Services returns do not cover Northern Ireland. This affects the comparison of the crude figures of expenditure and of estimated national income but should not materially affect the subsequent analyses given in the table.

By far the most important event in the period was the introduction of the National Health Insurance Scheme under the National Insurance Act of 1911. This was based on a new principle. Hitherto most of the services provided had developed from the old Poor Law and were therefore subject only to recoveries from recipients or their relatives who were able to make a a contribution ; and the amounts recovered were very small in proportion to the cost of the services. This new scheme —the forerunner of the much more elaborate and comprehensive schemes with which we are now familiar—was the first to be based on the principle of mutual insurance involving the payment by the insured person and by his employer of contributions during employment. These were paid into a common fund, from which cash benefits were paid to him, and medical treatment was provided for him, during sickness. Here a big gap develops between gross expenditure and publicly-borne expenditure, for the State contributed only a proportion of the cost of the benefits. Thus we find that against publicly-borne expenditure of nearly £12m quoted for 1920–21 in the table the gross expenditure was about £30m.

Another parallel development was the introduction under the same Act of the first Unemployment Insurance Scheme which was at first limited to a few selected ' skilled ' industries such as shipbuilding, mechanical engineering and iron founding with marked fluctuations in employment, covering some 2½ million workers. During the 1914–18 war munition workers were brought into the scheme and under an Act of 1920 it was extended to cover over 11 million workers (excluding only agriculture and domestic service) and provided considerably increased rates of benefit.

Another new development in the period was the introduction of the Maternity and Child Welfare Services operated by local authorities with 50 per cent. Exchequer grant. This followed the provision of similar services on a more rudimentary scale by voluntary bodies and a few local authorities for many years before the war.

Still another very important development was the introduction of State subsidies for housing under the Housing Act of 1919. This followed the realisation that, already deplorably low, pre-war housing standards had further deteriorated, e.g. as regards overcrowding, owing to the suspension of building during the war ; and that, because of the huge rise in costs, house building for renting by private enterprise could not, for a very long time at least, again become an economic proposition. The provision of houses for letting to the lower income groups was accordingly made the responsibility of the local authorities with State assistance ; in other words, housing in its own right, as distinct from housing incidental to the clearance of insanitary areas, became a public Social Service.

The first Act provided for the State meeting the local authorities' annual loss in excess of the produce of a penny rate ($\frac{4}{5}$ of a penny in Scotland) ; thus the local authority liability was limited while that of the State was unlimited. This was not calculated to encourage local authorities to practice economy, and despite close departmental control, building costs were enormous—not far short of those now

prevailing, although the general price level was only about two-thirds of the 1949–50 level.

The 1919 Act was therefore superseded by an Act of 1923 which provided fixed annual subsidies from the Exchequer related to average annual loss based on average data. Since then successive Acts have varied the amount of subsidy upwards or downwards according to conditions or the views of the Party in power, but the principle of the fixed Exchequer subsidy has been maintained, accompanied latterly by provision for a fixed rate contribution of one-half or one-third of the Exchequer subsidy. During the last few years the Exchequer subsidy and rate contribution together have been unable to bridge the gaps between rents and loan charges; and as the Government have not seen their way to increase the Exchequer subsidy, the local authorities have had to face the alternative of increasing rents to the full extent commensurate with the increases in price levels and wages, or of meeting the deficit by additional rating.

The annual Exchequer subsidies and rate contributions are payable over a period of years. The 1919 Act subsidies are payable so long as the loss arising on the houses built under that Act exceeds the produce of a 1*d.* rate; and that means 60 years since that generally is the period of redemption of the capital debt. Under the 1923 Act, the subsidy period was 20 years; under the 1924 Act and later Acts, 40 years, and for houses built since since 1946, 60 years. Thus it is that the 1920–21 column shows only a modest increase in public expenditure on housing because only the first few annual subsidies had begun to be paid. By glancing along this line of the table you will see the full snowball effect of the cumulative annual subsidies and rate contributions as more and more State assisted houses were built each year.

The enormous increase in the cost of Education, from £32m to £85m, was due to the operation of the Education Act, 1918, giving practical application to the full conception of universal secondary and further education, with assistance by way of bursaries to provide equality of opportunity; and to a spectacular improvement in teachers' salary scales and pension schemes.

In spite of these developments, the additional public expenditure on which in 1920–21 amounted to about £70m, accompanied by the inevitable rise in the costs of the services already established to compensate for the fall in the value of the £1, you will see that the rate per £1 of national income rose only very slightly above the 1910–11 figure.

11. 1925–26

This year saw the passing of the first Contributory Widows, Orphans and Old Age Pensions Act, which provided on a mutual insurance basis and as a right, subject to the satisfaction of certain insurance qualifications but without any means test, pensions for widows (with children's allowances), old age pensions for persons aged 65 to 70, and allowances for orphans. On reaching the age of 70 the holders of widows' and 65–70 pensions became entitled to pensions under the original non-contributory scheme but still without having to undergo any means test. The scheme was limited to persons in insurable employment—to manual workers and to non-manual workers with incomes not exceeding £250 p.a. increased in 1942 to £420 p.a.; and there was provision for persons who had been in insurable employment and had the necessary qualifications, continuing in, or re-entering, insurance as voluntary contributors. The machinery of the scheme was superimposed on the health insurance scheme so that contributions, by way of stamped cards, were collected together and, with very few minor exceptions, persons insured under the one scheme had also to be insured under the other. By this stage the scheme had scarcely got going and the charge of £4m shown in the 1925–26 column represents the first Exchequer payments into the Treasury Pensions Account which fed the Departmental Pensions Accounts against which the pensions were charged.

The State's liability in respect of unemployment insurance had risen from £3m in 1920–21 to £13·5m in 1925–26. After the early post-war boom years when contributions exceeded expenditure and reserves were being built up, the scheme

fell on evil times because of the slump which followed. Insurance principles were abandoned to extend unemployment benefit rather than force hundreds of thousands of able-bodied employed and their familes on to the unpopular Poor Law; the Fund's reserves were soon exhausted and heavy borrowing was resorted to. Comparison of the full returns for 1920–21 and 1925–26 shows that the gross expenditure from the funds had risen from £10·8m in 1920–21 to practically £50m in 1925–26. The average number of unemployed had risen from under half a million in 1920 to about 1·25m in 1925–26, or 10·7 per cent. of the insured population.

There is one curious feature in this column. In an otherwise rising tide of expenditure, the Exchequer expenditure on the Health Insurance Scheme has dropped from £11·7m to £7·1m. This is not due to any curtailment of the scope of the scheme. On the contrary, the gross expenditure from the National Health Insurance Funds had risen from £29·9m in 1920–21 to £36·6m in 1925–26. The reason is that one of the economy measures decided on by the Government at that time was a substantial reduction in the rates of State grant on benefits fixed by the 1911 Act. These now averaged only about 16 per cent. compared with the original average of about 23 per cent.

Housing expenditure by now was getting into its stride, having jumped from £0·75m in 1920–21 to over £10m in 1925–26—the snowball which I mentioned in operation. By now some 430,000 houses had been completed.

This is an appropriate point at which to consider the development of a long term trend, viz. the growth in the share of the burden of Social Services borne by the State. I have mentioned that in the nineteenth century the State's direct share in the cost of Social Services was negligible, except for education. By 1910–11 the State's direct share of the burden, both actual and proportionate, had gradually increased but, excluding the indirect share borne under the Local Taxation Account arrangements, the Exchequer was still bearing only about 48 per cent. of the total public expenditure. By 1925–26 the proportion had risen to about 58 per cent.

The publicly-borne expenditure per £1 of national income shows the most substantial rise so far recorded in this table; the 1920–21 rate of 7¼*d.* has increased by over 70 per cent. in 1925–26—to 1*s.* 0½*d.*

12. 1930–31

The chief feature of 1930–31 compared with 1925–26, over a period when price levels had fallen quite appreciably, is the enormous increase in the cost to the State of unemployment insurance. The unemployment position was then worse than in 1925–26; this was the period of the great depression when the maximum number of unemployed topped the 2½ million mark, the average number for 1930–31 being about 2·2 million or about 18 per cent. of the insured population. Of the £35m representing the total State expenditure on unemployment insurance, no less than £20m was spent on the payment of 'transitional' benefit—to workers who had exhausted their ordinary benefit rights.

The year also shows an increase from £4m in 1925–26 to £9m in payments into the Treasury Pensions Account feeding Departmental Pensions Accounts to which the contributory pensions and allowances were charged and an increase of about £8m under the head of non-contributory pensions. This reflects the normal growth in the numbers of people becoming entitled to benefits under the Contributory Act or to consequential over-70 old age pension (without means test).

It is rather significant that despite the increase in the volume of unemployment the burden of poor relief on the local authorities actually fell in 1930–31 compared with 1925–26, a measure of the extent to which the State had stepped in to shoulder it.

The increase in expenditure on housing reflects the accumulation of subsidies on houses completed since 1925–26 on the subsidies already current at that date and still continuing. By now over 1,100,000 houses had been completed.

The appropriation per £1 of national income had arisen appreciably to 1*s.* 4*d.*—practically all the increase being attributable to State as distinct from local authority expenditure.

13. 1935–36

The further enormous increase in State expenditure on unemployment insurance is not quite so bad as it looks in comparison with 1930–31. It is largely due to a re-arrangement of finance under an amending Act of 1934. This Act tightened up administration, stopped borrowing by the Unemployment Insurance Fund, increased the employers' and employees' contributions, and changed the basis of the State grant, relating it to the employers' and employees' contributions paid into the Fund. It also, however, charged wholly and directly against the Exchequer the 'transitional' benefit, the burden of which had hitherto been partly borne by the Unemployment Insurance Fund.

Thus the actual expenditure from the Insurance Fund on unemployment benefit proper amounted in 1935–36 to about £52m whereas the receipts into the Fund amounted to £66m of which £44m represented contributions and £22m represented State grant. But the full cost of transitional benefit was enormous, amounting to nearly £47m.

The 1934 Act also set up the first Unemployment Assistance Board to take over from the Poor Law Authorities the responsibility for all persons (including their families) whose normal occupation had brought them under the Contributory Pensions Act (which was our widest social insurance), and who were 'capable of and available for work.'

The average number of unemployed over this year had fallen slightly to about 1·9 million or about 15 per cent. of the insured population.

For the continuing reasons already given the Exchequer payments into the Treasury Pensions Accounts and the charges under the non-contributory O.A.P. Act rose steadily over the period.

The cost of education continued to rise steadily, reaching £103·5m in 1935–36. I have no details for that year but the P.E.P. Social Services Report contains a very useful analysis of the expenditure of about £100m in the preceding year 1934–35 between salaries, maintenance charges and loan charges and administration. It also shows that the expenditure over the U.K. was met to the extent of about 47 per cent. from the Exchequer, 48 per cent. from local rates and 5 per cent. from other sources.

Expenditure on hospitals shows quite an appreciable rise. This was the effect of the Local Government Act of 1929 which *inter alia* authorised local authorities to 'appropriate' poor law hospitals and convert them into public hospitals, or alternatively to build general public hospitals. These powers were extensively used in England and Wales (though not to any extent in Scotland) with the result that at the outbreak of the war the number of beds available in general public hospitals was about double the number available in voluntary hospitals.

In spite of the growth of the many other forms of public social provision, poor relief or public assistance remained one of our major public social services. In 1935–36 it still accounted for 15 per cent. of the net public expenditure on the services. Although it had lost most of its harsh and deterrent features it was a service to which few people had recourse unless they had exhausted all other reasonable means of meeting their needs. Nevertheless over 1·6m people (including dependants) were actually in receipt of poor relief in Great Britain on 1st January, 1936, of whom about 200,000 were on institutional relief and the remainder on domiciliary relief.

Housing expenditure had risen to £19·7m. By now the total number of State assisted houses had risen to over 1,450,000.

The rate per £1 of national income diverted to meet public expenditure on Social Services had risen to 1*s.* 7¾*d.*

14. 1947–48

It is now necessary to jump the war period straight to 1947–48; not very much is missed, however, for, even if full information were available, the figures for any of the war years or the first two years following the war would probably be rather distorted owing to the numerous fields in which the State had to intervene to meet abnormal conditions, e.g., in bearing a share of voluntary and local authority hospital expenditure in respect of empty beds kept available for battle and air-raid casualties; and for E.R.O. —the Emergency Relief Organisation.

We could never have been quite certain that all this abnormal expenditure was definitely excluded from the figures extracted, whereas we can be pretty certain that in 1947–48 it had virtually disappeared and that by then we were back on a new post-war level. This is also the best of the post-war years to take, being the last complete financial year before the 'appointed day'—5th July, 1948—which saw the introduction of the new comprehensive National Insurance, National Health, and National Assistance schemes.

The only new development preceding these big changes which were to follow in the summer of 1948 was the introduction of family allowances under the Act of 1945. These allowances, at the rate of 5*s*. for all children, excluding the first in each family, became, and still remain, a direct charge on the Exchequer and do not form part of the insurance system.

The most gratifying feature of the table, against an overall increase in the crude figures compared with 1935–36, is the big drop in the amount of State grant for unemployment insurance. As a matter of fact the position is far better than it looks. From figures which would have been provided in a complete version of the Social Services Return, although omitted from the abridged version, it appears that the total expenditure on unemployment insurance and its administration was only £26m ; against this, receipts into the fund amounted to about £97m of which the £28m quoted in the table is State grant and the balance of £69m represents employers' and employees' contributions and income from investments ; so the Fund was already building up quite a useful reserve during the period of virtually full employment against a possible slump.

There is an enormous jump in the payments into the Treasury Pensions Account, arising from the transfer from the Old Age Pensions Vote to the Pensions Account of liability for over-70 old age pensions payable by virtue of the Contributory Pensions Act, and the increase of O.A.P. rates from 10*s*. to 26*s*. per week from October 1946 in anticipation of the 'Appointed Day,' viz. July 5, 1948, fixed for the other provisions of the National Insurance Act, 1946. Without the transfer of liability for these over-70 old age pensions, the charge shown against old age pensions in 1947–48, a consequence of the higher rates of pensions and the growing number of pensioners, would have been far greater than the corresponding charge for 1935–36, instead of showing a reduction.

The cost of Education soared from £103m in 1935–36 to £231m in 1947–48. This was of course due mainly to the fall in the value of the £1. There had been, however, an important development just before this which should not be overlooked—the passing of the Education Act, 1944, and the corresponding Scottish Act of 1945. These Acts provided for the raising of the school leaving age to 15—which actually took effect from April 1947—and for the development of social and recreational training and its extension to cover not only the youth of the country but the whole community. The effect of these developments on 1947–48 expenditure was slight, but it has now become substantial.

Housing expenditure has jumped from £19·7m in 1935–36 to £42m in 1947–48. This represents accumulated annual subsidies on about 2,120,000 houses of which 1,810,000 were completed between the two wars and 310,000 since the last war—the subsidies on the latter, owing to the huge rise in building costs, being at greatly increased rates. Nearly half the post-war houses were temporary houses, covered by special financial arrangements which involve a very heavy, but relatively short-term, burden on the Exchequer.

Expenditure on all the other existing services shows inevitable increases in 1947–48 compared with 1935–36, in consequence of the fall in the value of the £1. You will note, however, that even the crude expenditure on poor relief shows a very small increase. Equated to the standard price level the variation represents a drop of almost 50 per cent.—an indication of the further lifting of the relative burden from the shoulders of the local authorities. The Exchequer share of the publicly-borne expenditure on all services had risen to 68 per cent., apart from the share of local authority expenditure covered by the block grant.

Generally you will see that the rate of

public expenditure per £1 of national income has fallen from 1*s.* 7¾*d.* in 1935–36 to 1*s.* 4*d.* in 1947–48—in other words, notwithstanding the important developments already noted, public expenditure on the Social Services has not quite kept pace with the inflationary post-war increase in the national income.

15. 1949–50

So now we come to 1949–50, the last year for which complete financial records are available, and the year which marks the completion of the century we have been reviewing.

It is hardly necessary for me to attempt to outline the three new schemes—National Insurance, National Health, and National Assistance—which came into operation on the same Appointed Day—July 5, 1948; for as you are interested enough in Social Services to have come here to-day, most of you will already have a very good idea of what they cover and how they operate.

In this table it has been necessary to adopt a condensed version of the classification used in Table 151 of the May issue of the 'Monthly Digest of Statistics,' but as far as possible the new items have been placed opposite the old items to facilitate comparison.

The Return purports to be on a net 'publicly-borne' basis, for the heading 'Expenditure of Public Authorities on the Social Services' is footnoted to repeat that the figures represent the cost borne by public authorities. I find, however, that in the case of the new comprehensive contributory insurance scheme, the expenditure is gross, i.e., it includes expenditure met out of contributions paid by and on behalf of insured persons as well as out of State grant. It is quite true that it is gross income and expenditure that pass through the National Insurance Fund, but as I have hitherto confined my review to publicly-borne expenditure in the narrower sense of expenditure borne by the State and by local authorities, i.e., charged against Imperial taxation and local rates, it is necessary for consistency and for comparison to apply a similar restriction to 1949–50. Turning therefore to the 1949–50 account of the National Insurance and Industrial Injuries Funds and to the Appropriation Account of the Ministry of National Insurance, we find the position to be roughly as follows:—

| | £m | £m |
|---|---|---|
| Contributions by and on behalf of insured persons | 430·9 | |
| Exchequer contributions (as shown in Appendix) | 147·5 | |
| Other receipts (interest, etc.) | 26·9 | |
| | | 605·3 |
| Benefits paid (the figure in the Return) | 377·9 | |
| Contribution to National Health Service | 40·0 | |
| Other expenditure and administration | 26·3 | |
| | | 444·2 |
| Surplus for year approximately | | £161m |

The accumulated surplus on these funds at March 31, 1950 (including earlier surpluses taken over from the funds existing before the Appointed Day), was about £373m plus some £786m held in the National Insurance (Reserve) Fund—in all about £1,160m. The reduction in the Exchequer contribution intimated by the Chancellor in his Budget speech this year (1951) and effected in the National Insurance Act, 1951, is designed to stop further accumulations of large annual surpluses.

By comparing the first three items in the 1947–48 column of the table with the direct charge against the Exchequer in respect of the new contributory scheme in 1949–50 you will see that there has actually been a slight reduction, even allowing for the fact that the charge for the old National Health Insurance Scheme includes an element—State grants on medical benefit and certain treatment benefits—which is now merged in the National Health Service; so the bulk of the additional requirements of the new insurance scheme are being met by contributions of insured persons and their employers.

You will notice that family allowances, being universally payable, are still a direct charge on the Exchequer. So are the non-contributory old age pensions

which are now administered by the National Assistance Board. This, of course, is a diminishing charge as this oldest generation of pensioners, without any insurance qualifications, gradually dies out.

The cost of the National Health Service is put at £408·6m. This appears to represent the gross expenditure from the two Health Votes (including the credit of £40m from the National Insurance Fund), plus the local authority proportion of the cost of the domiciliary health services, less the small amount of recoveries from Staff for board and lodging and from the public, e.g., for pay-beds. This appears a very heavy burden for the country to bear but to some extent it represents a continuance of expenditure which, before the Appointed Day was being met otherwise than from the Exchequer, e.g., in payment of doctors', dentists', opticians' and chemists' bills out of private pockets, and the running costs of voluntary and local authority hospitals now taken over.

Before I leave the National Health Service there is one other point I should like to be allowed to make, to try once again to correct a misconception in the minds of many otherwise well-informed persons. The main charge for this service —covering the hospital, medical, dental, pharmaceutical and ophthalmic services— does *not* fall on National Insurance contributions; these are required to meet cash benefits, allowances, and pensions during sickness, unemployment, widowhood and old age. The only link between the two Schemes is the appropriation I have already referred to of about £40m p.a. from the National Insurance Fund in aid of the National Health Service. This represents on the average only about 7 per cent. of the total contributions plus State grant, paid into the National Insurance Fund; and only about 9 per cent. of the gross cost of the National Health Service; the entire balance of this expenditure, apart from certain recoveries on a relatively small scale in respect of pay-beds and staff board and lodging, is a direct charge on the Exchequer. So it is the taxpayer and not the insured person who is meeting by far the major part of the Bill for the National Health Service; and the fairly widespread impression to the contrary should be corrected whenever possible.

Housing expenditure continued to rise owing to the superimposing of the subsidies and rate contributions at the higher post-war rates on those already in payment; the total numbers of houses completed up to 1949–50 had risen to almost 2½ million including nearly 700,000 post-war. The expenditure here is definitely net publicly-borne expenditure in the narrower sense, for there is a specific set-off in respect of rent receipts.

From the new version of the Return it is impossible to state definitely how much of the publicly-borne expenditure is met from the Exchequer and how much from local rates but on a rough calculation I estimate the local authorities' share to be not more than about one-eighth, and some proportion of this is recovered by local authorities from the Exchequer through the Equalisation Grant.

There is, however, quite a useful split between Exchequer and Local Authority expenditure in the case of poor relief; for now the whole burden of what was formerly known as out relief has been taken over in the name of National Assistance, by the National Assistance Board—to the tune of about £49m in 1949–50—leaving the local authorities with only the indoor maintenance of the aged poor, at a cost of only about £7m in 1949–50. The institutions in which these aged poor are now maintained are becoming more and more unlike the poorhouse and workhouse of the old regime, developing into something more in the nature of Eventide Homes run in a spirit of humanity which appears to have been sadly lacking in the old days.

The appropriation per £1 of national income to meet Exchequer and local authority expenditure on the Social Services is now estimated to have risen to 2*s*. 1¾*d*. representing a 60 per cent. increase over 1947–48; but as already stated some of this represents expenditure of which the equivalent, before the Appointed Day, was met from private purses and through voluntary agencies.

16. *Retrospect*

I trust that this Paper, sketchy as it necessarily is, has given a fair idea of the

century's progress in social services as measured by the growth of public expenditure.

The main legislative landmarks which stand out over a period have already been indicated. Between those landmarks development and expansion have been empirical and at times sporadic but seldom if ever has there been any regression, for most services have only come under pressure of enlightened public opinion and when the need for them has been clearly seen.

The main trends in the development of the services as we now know them seem to have been :—

(1) The evolution of public social services out of voluntary social services.

(2) The movement away from a comprehensive Poor Law Service based on destitution to a number of specialised services based on common citizenship.

(3) The widening of the administrative unit from the local authority to the State, operating sometimes on a regional basis.

(4) The corresponding transfer of the major share of the financial burden from the local authorities to the Exchequer.

(5) The adoption by the State, borrowing from the experience of Friendly Societies and Trade Unions, of the principle of mutual insurance for the payment of cash benefits during sickness and unemployment, and for the payment of pensions and allowances for old age and to widows and orphans—replacing the poor relief which was the only source of assistance to former generations in similar circumstances.

The total 'cover' afforded by the various schemes which had come into operation before July 5, 1948, was already pretty comprehensive. But they were not well integrated. There were many gaps and some quite indefensible anomalies.

These anomalies are swept away in the new National Insurance Scheme under which the rates of payment of benefit in different circumstances have been integrated and rationalised, due regard being had to the greater needs of the family man compared with the bachelor.

To conclude this summing up I feel I cannot do better than quote from the introduction of a pamphlet published by the Central Office of Information in February 1951 on the British system of Social Service, which gives a very much better picture of the final development of the social services than I possibly could.

> 'Social insurance in Britain, as a function of the State, has been gradually built up over three centuries, by the promptings of an awakening social conscience and an increasing sense of interdependence within the community. The movement has steadily given shape to the idea that the State should offer its citizens a general condition of security in which to pursue their careers and fulfil their duties. It has aimed at giving the individual freedom from want without prejudicing his rights. Two basic principles have emerged in the process : one, that the citizen should get security, not for nothing, but in return for service and contribution ; and secondly, that the guarantee of State help should not stifle the individual's will to self-help.
>
> Social insurance is not the only manifestation of a State social conscience. The National Health Service, the national education system, and the other social services in the fields of housing, town and country planning, legal aid and welfare work are all parts of the same picture and all are infused with the same principle of co-operation between the State and the individual. They also display, perhaps in a measure not achieved in any other country, the successful application of the principle that the obligations of the community to the individual should be assessed upon his needs rather than upon his nationality, industrial status, social position, or membership of a political party.'

17. *Conclusion*

And with that borrowed peroration I conclude this paper, ending, as I began, on the apologetic note. I am painfully aware of many defects and omissions. This is due partly to the time factor, for the subject is too vast to be adequately dealt with in the short space of an hour ; and partly to the fact that mine has been the narrower approach of the accountant

rather than the wider approach of the economist or social historian, which would have been more appropriate for this audience.

There are many questions to which I might have tried to address myself if time had permitted—such questions for example as :—

Whether under present conditions we can afford our Welfare State (in particular reference to the insurance contributions which are so heavy an 'oncast' on industry) or as some people would prefer to put it, whether we can afford *not* to have it.

To what extent the 'cover' now provided by the Social Services represents additions to real incomes which should be taken into account in wage negotiations.

The suggestions which have recently been put to the Royal Commission on Taxation as to the merging of social insurance contributions with a simplified Income Tax and the suppression of insurance cards.

All these questions and many others are of interest to the economist. We are not able to discuss them here ; but if I have succeeded in this review in providing any useful data for others to follow up in a wider and more thorough study of the development of the Social Services, then, to adopt the words of a popular song, I can feel that my appearance before you to-day has not been in vain !

SOURCES OF INFORMATION

*Official Publications*

(*a*) Statistical abstracts (old style) covering the period 1857 to 1928, prepared by the Statistical Department of the Board of Trade.

(*b*) The Public Social Service Returns for the inter-war period, and for 1947–48.

(*c*) Public Health and social conditions—statistical memoranda and charts published by the Local Government Board for England in 1909 (referred to for convenience as the 'L.G.B. Blue book').

(*d*) Economic surveys for the years 1946–1951.

(*e*) National Income and Expenditure of the United Kingdom 1946–1950.

(*f*) Statistical abstract for the U.K. (new style) 1938–1948.

(*g*) 'Monthly Digest of Statistics' for May, 1951, containing the latest version of the Public Social Services Return—for the year 1949–1950.

*Unofficial books and pamphlets*

(*h*) P.E.P.'s Report on the British Services.

(*i*) Colin Clark's *National Income and Outlay* (1937).

(*j*) The 'Economic Journal' of March 1948, containing a survey of the National Income of the U.K. 1870–1946, by Mr. A. R. Prest of the Department of Applied Economics, Cambridge.

(*k*) A paper on the Public Social Services given to the Royal Statistical Society in May 1937, by Sir Gwilym Gibbon and reprinted from their Journal, Volume C, Part IV, 1937.

Statement showing, at intervals over the period 1851 to 1949–50, (*a*) the gro
and (*c*) the amount per £1 of the a

| Year | 1850–51 | |
|---|---|---|
| | Amount £000 | % |
| 1. *Social Service Expenditure*—(publicly borne) | | |
| Unemployment Insurance Acts, etc. | — | |
| Health Insurance Acts | — | |
| Widows Orphans and Contributory O.A.P. Acts | — | |
| Contributory Insurance Schemes (1949–50) | — | |
| Family Allowances Act | — | |
| O.A.P. Acts—Non-Contributory and Supplementary Pensions | — | |
| Education Acts, etc., (including approved schools) | 200 | 2· |
| Miscellaneous Nutrition Services, etc. (1949–50) | — | |
| Public Health Acts—Hospitals | — | |
| Maternity and Child Welfare, Midwives Act, etc. | — | |
| Lunacy and Mental Treatment, and Mental Deficiency Acts | — | |
| National Health Service (1949–50) | — | |
| Housing | — | |
| Relief of the Poor | 6,800 | 97· |
| National Assistance—(1949–50)—Exchequer | — | |
| Local Authorities | — | |
| Administration (Central) (1949–50) | — | |
| Total of Item 1 . . . £000 | 7,000 | 100· |
| 2. Estimated National Income at current prices—U.K. to 1910–11 ; G.B. from 1920–21 . . . £000 | 600,000 | |
| 3. Ratio of item 1 to item 2 | 1·17 % | |
| 4. Population—thousands—U.K. to 1910–11 ; G.B. from 1920–21 | 27,370 | |
| 5. Public Expenditure on Social Services—Item 1—per head of population (actual) £ | 5 1 | |
| 6. Comparative price index—standard year 1900 | 98 | |
| 7. Public Expenditure on Social Services per head of population equated to 1900 price level £ | 5 3 | |
| 8. Average Income per head of population—actual £ | 21 18 0 | |
| 9. Average Income per head of population—equated to 1900 price level £ | 22 7 0 | |
| 10. Amount per £1 of average income diverted to meet public expenditure on social services | 2¾*d.* | |

# APPENDIX

0, (*a*) the growth of Social Service expenditure borne on the Exhequer and on local rates ; (*b*
£1 of the average individual share of the national income diverted by the State and by loca

| 1850–51 | | 1870–71 | | 1890–91 | | 1900–01 | | 1910–11 | | 1920–21 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Amount £000 | % | Amount £000 | % | Amount £000 | % | Amount £000 | % | Amount £000 | % | Amount £000 | % |
| — | | — | | — | | — | | — | | 3,092 | 1 |
| — | | — | | — | | — | | — | | 11,739 | 7 |
| — | | — | | — | | — | | — | | — | |
| — | | — | | — | | — | | — | | — | |
| — | | — | | — | | — | | — | | — | |
| — | | — | | — | | — | | 7,360 | 12·4 | 20,750 | 12 |
| 200 | 2·9 | 2,400 | 20·0 | 12,400 | 52·9 | 20,600 | 56·4 | 32,363 | 54·6 | 85,467 | 52 |
| — | | — | | — | | — | | — | | — | |
| — | | — | | 500 | 2·2 | 1,480 | 4·0 | 2,103 | 3·5 | 5,150 | 3 |
| — | | — | | — | | — | | — | | 1,666 | 1 |
| — | | — | | 700 | 3·0 | 1,200 | 3·3 | 1,734 | 2·9 | 1,850 | 1 |
| — | | — | | — | | — | | — | | — | |
| — | | — | | 75 | 0·3 | 170 | 0·5 | 264 | 0·5 | 738 | 0 |
| 6,800 | 97·1 | 9,600 | 80·0 | 9,750 | 41·6 | 13,050 | 35·8 | 15,490 | 26·1 | 33,234 | 20 |
| — | | — | | — | | — | | — | | — | |
| — | | — | | — | | — | | — | | — | |
| — | | — | | — | | — | | — | | — | |
| 7,000 | 100·0 | 12,000 | 100·0 | 23,425 | 100·0 | 36,500 | 100·0 | 59,314 | 100·0 | 163,676 | 100 |
| 600,000 | | 929,000 | | 1,399,000 | | 1,756,000 | | 2,063,000 | | 5,494,000 | |
| 1·17 % | | 1·3 % | | 1·7 % | | 2·1 % | | 2·9 % | | 3·0 % | |
| 27,370 | | 31,214 | | 37,734 | | 41,459 | | 45,222 | | 42,769 | |
| 5 1 | | 7 8 | | 12 5 | | 17 7 | | 1 6 3 | | 3 16 6 | |
| 98 | | 122 | | 98 | | 100 | | 106 | | 260 | |
| 5 3 | | 6 3 | | 12 8 | | 17 7 | | 1 4 9 | | 1 9 | |
| 21 18 0 | | 29 15 0 | | 37 1 0 | | 42 7 0 | | 45 12 0 | | 128 9 | |
| 22 7 0 | | 24 8 0 | | 37 17 0 | | 42 7 0 | | 43 1 0 | | 49 8 | |
| 2¾*d.* | | 3*d.* | | 4*d.* | | 5*d.* | | 7*d.* | | 7¼*d.* | |

## NDIX

he Exchequer and on local rates ; (*b*) the expenditure per head of population—actual and equated to the 1900 price level ; e diverted by the State and by local authorities to the provision of Social Services.

| 1 | 1910–11 | | 1920–21 | | 1925–26 | | 1930–31 | | 1935–36 | | 1947–48 | | 1949–50 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | Amount £000 | % | Amount £000 | % | Amount £000 | % | Amount £000 | % | Amount £000 | % | Amount £000 | % | Amount £000 | % |
| | — | | 3,092 | 1·9 | 13,504 | 6·7 | 35,500 | 13·9 | 68,752 | 21·0 | 28,404 | 4·4 | — | |
| | — | | 11,739 | 7·2 | 7,100 | 3·5 | 7,074 | 2·8 | 7,450 | 2·3 | 11,002 | 1·7 | — | |
| | — | | — | | 4,000 | 2·0 | 9,000 | 3·5 | 14,000 | 4·3 | 117,025 | 18·1 | — | |
| | — | | — | | — | | — | | — | | — | | 147,500 | 12·7 |
| | — | | — | | — | | — | | — | | 58,612 | 9·0 | 60,900 | 5·2 |
| | 7,360 | 12·4 | 20,750 | 12·7 | 27,953 | 13·8 | 37,520 | 14·7 | 43,774 | 13·3 | 40,336 | 6·2 | 26,700 | 2·3 |
| 6·4 | 32,363 | 54·6 | 85,467 | 52·2 | 85,443 | 42·3 | 96,093 | 37·5 | 103,503 | 31·6 | 230,780 | 35·6 | 268,600 | 23·1 |
| | — | | — | | — | | — | | — | | — | | 71,500 | 6·2 |
| 4·0 | 2,103 | 3·5 | 5,150 | 3·1 | 6,912 | 3·4 | 8,525 | 3·3 | 13,794 | 4·2 | 40,559 | 6·2 | — | |
| | — | | 1,666 | 1·0 | 1,724 | 0·8 | 2,198 | 0·9 | 3,079 | 0·9 | 14,220 | 2·2 | — | |
| 3·3 | 1,734 | 2·9 | 1,850 | 1·1 | 3,739 | 1·9 | 4,115 | 1·6 | 5,530 | 1·7 | 13,430 | 2·1 | — | |
| | — | | — | | — | | — | | — | | — | | 408,600 | 35·2 |
| 0·5 | 264 | 0·5 | 738 | 0·5 | 10,211 | 5·1 | 16,427 | 6·4 | 19,728 | 6·0 | 41,985 | 6·5 | 54,500 | 4·7 |
| 5·8 | 15,490 | 26·1 | 33,234 | 20·3 | 41,503 | 20·5 | 39,469 | 15·4 | 48,339 | 14·7 | 51,668 | 8·0 | — | |
| | — | | — | | — | | — | | — | | — | | 49,200 | 4·2 |
| | — | | — | | — | | — | | — | | — | | 7,100 | 0·6 |
| | — | | — | | — | | — | | — | | — | | 67,400 | 5·8 |
| 0·0 | 59,314 | 100·0 | 163,676 | 100·0 | 202,089 | 100·0 | 255,921 | 100·0 | 327,949 | 100·0 | 648,021 | 100·0 | 1,162,000 | 100·0 |
| 0 | 2,063,000 | | 5,494,000 | | 3,861,000 | | 3,838,000 | | 3,986,000 | | 9,520,000 | | 10,864,000 | |
| | 2·9 % | | 3·0 % | | 5·2 % | | 6·7 % | | 8·2 % | | 6·8 % | | 10·7 % | |
| 9 | 45,222 | | 42,769 | | 43,800 | | 44,795 | | 45,600 | | 48,220 | | 48,992 | |
| 7 | 1 6 3 | | 3 16 6 | | 4 12 3 | | 5 14 3 | | 7 3 9 | | 13 4 7 | | 23 14 4 | |
| 0 | 106 | | 260 | | 190 | | 167 | | 159 | | 329 | | 393 | |
| 7 | 1 4 9 | | 1 9 5 | | 2 8 7 | | 3 8 5 | | 4 10 5 | | 4 0 5 | | 6 0 8 | |
| 0 | 45 12 0 | | 128 9 0 | | 88 3 0 | | 85 14 0 | | 87 8 0 | | 197 9 0 | | 221 15 0 | |
| 0 | 43 1 0 | | 49 8 0 | | 46 8 0 | | 51 6 0 | | 55 0 0 | | 59 14 0 | | 56 9 0 | |
| | 7*d.* | | 7¼*d.* | | 1*s.* 0½*d.* | | 1*s.* 4*d.* | | 1*s.* 7¾*d.* | | 1*s.* 4*d.* | | 2*s.* 1¾*d.* | |

# A HUNDRED YEARS OF ORGANIC CHEMISTRY[1]

by

PROF. A. R. TODD, F.R.S.

IT seems peculiarly apt to choose this year of 1951 as an occasion for looking at a century of organic chemistry because it is effectively within the period 1851–1951 that it has grown from a state of chaos into perhaps the most highly systematic of all the sciences, as well as one of the largest both in content and in the number of its adherents. Whether I am the right person to discuss it is more doubtful; I am no historian and there are several well-known authorities on the history of chemistry in this country whose knowledge of the facts and of the fascinating stories of individual discoveries vastly exceeds my own. Nevertheless, it may be of some interest if I, as a practising organic chemist, try to put before you a brief outline of what seem to me to be the important landmarks in the science during the century under review and to give a purely personal picture of the various trends which together have gone to make the science what it is.

Organic chemistry in 1851 was a rather fantastic subject and had indeed been described by Wöhler as a trackless jungle. True, there were a lot of facts known, but factual knowledge had far outstripped theory. It was convenient for Berzelius and his contemporaries at the beginning of the nineteenth century to describe organic chemistry as the chemistry of substances produced by living matter, and to set it apart from inorganic chemistry, which dealt with non-living or mineral materials, but in many respects this division was little more than a recognition of the fact that organic substances had very different properties from inorganic and that no one knew why they should so differ. It was, of course, maintained that the production of organic substances required a 'vital force' but this again is best regarded as an expression to cover the unknown (the term 'steric hindrance' was used a hundred years later to serve not dissimilar purposes).

[1] Paper read to the Chemistry Section at Edinburgh on August 9, 1951.

The famous Wöhler synthesis of urea (1828), generally said to have finished the vital force theory, did not in fact do so, and it lingered on in one form or another for a long time—it can be found in Gmelin's textbook published in the early 1850's. However, it quickly became apparent that the common feature of organic compounds was that they contained the element carbon and that little progress would be made in organic chemistry until a lot more was learnt about carbon. It is this fact which Gmelin stressed and which has given rise to the common view that he defined organic chemistry as the chemistry of the carbon compounds—a view which is not borne out if the relevant parts of his famous textbook are examined. Be that as it may, following the discovery of coal tar as a source of carbon compounds, the subject had gone ahead in this direction by 1850 and the amount of attention being paid to organic chemistry in the sense of its original definition was on the decline. But what a mess it was in!

The idea of 'one composition one compound' which seemed more or less true in inorganic chemistry was far from true in organic chemistry, for compounds seemed to abound which had the same elementary composition but which were quite obviously different from one another. The old type theories and radical theories designed to explain molecular structure were clearly inadequate and indeed gave no explanation of the facts which they related empirically. The real trouble was that there was as yet no clear idea of what we now call the valency or combining power of an element, nor was it realised that two or more atoms of one and the same element could join together just as easily as two unlike atoms. It was in 1852 that Edward Frankland first clearly enunciated the idea that an element has a limiting combining power or valence and this represents the first of our milestones. Within a few years, there came yet a further major advance in the work of Friedrich August Kekulé, a German, and

Archibald Scott Couper, a young Scotsman. In 1858 they published independently two papers which must rank high in the history of chemistry and which are essentially similar—another example of the way in which ideas seem to come frequently to fruition in various places about the same time. In brief, Kekulé and Couper accepted the tetravalency of carbon and the capacity of carbon atoms to link up with one another ; they were able on this basis to draw graphic formulae which at once explained the characteristic isomerism met with in organic (i.e. carbon) compounds and made possible the prediction of isomers. This was an enormous step forward and really set organic chemistry going as a science at last. During the next few years there were various modifications of these theories, e.g. by Crum Brown and Wurtz, followed in 1865 by Kekulé's famous paper on the constitution of aromatic compounds in which the structure of benzene—the familiar hexagon—was put forward. Perhaps, as Anschütz (*Ber.*, 1912, *45*, 539) says, the first exponent and discoverer of the ring structure was Loschmidt who published his paper on the same topic in Vienna in 1861, but the work of Kekulé was certainly that which made the real impression.

These theories of Kekulé and Couper were the solid foundation for the subject and I would say that with one addition —the Van't Hoff-Le Bel theories—they formed the whole basis of the towering edifice of modern organic chemistry. The only real difficulty about the Kekulé-Couper ideas was that there were in fact more isomers known than could be accounted for by their two-dimensional graphic formulae. In 1848, Louis Pasteur, studying the optical activity of the tartaric acids, had shown that there were *dextro*, *laevo*, and inactive isomers and that the optical isomers differed not merely in crystalline, but also in molecular, structure. He introduced, indeed, the concept of molecular asymmetry (mirror image molecules which are non-superimposable) but did not develop it. In 1874, however, Van't Hoff and Le Bel independently advanced the idea of the tetrahedral carbon atom, i.e. that valency bonds were oriented in space in a definite way. This finally brought molecular structure into three dimensions and gave us the theories of stereochemistry substantiated later by workers in many lands.

It is to me quite an astonishing thing that the theories mentioned above, even although they could be said to be purely empirical, have actually survived all assaults, and using them alone it is possible to develop well-nigh everything that makes up orthodox organic chemistry (to be complete one would have to add the equally empirical partial valency ideas of Thiele and others), although not really to *explain* it all.

Organic chemistry now had its basic theory and it went ahead at a tremendous pace. During the period to 1900 it developed a staggering array of facts and of methods for the structural elucidation and synthesis of carbon compounds. The chemistry of living matter languished somewhat and few chemists studied it, although one should remember that the great Baeyer's work on indigo, on anthraquinones and on the terpenes was done in this period. In part, of course, this lack of work on substances from living matter was due to the development of the great organic chemical industry, particularly in Germany, which emphasised the purely synthetic side. Nevertheless, it can be maintained that it was a necessary phase in the growth of the science because, until it had run its course, the methods essential to a successful attack on the chemistry of living matter simply did not exist ; in the latter half of the nineteenth century, organic chemists were really forging their weapons.

With the beginning of the twentieth century, a new trend in the subject made its appearance. It was almost a natural consequence of the state of perfection in methods which had been reached, and it originated largely in the school of Adolf Baeyer, perhaps the greatest master of the subject and certainly leader of the greatest school in Germany—one in which our own W. H. Perkin, Jr., developed. This new trend marked the beginning of the return of organic chemistry to its original objective and definition—the chemistry of the substances found in living matter. Among its early exponents we find such

great names as those of Emil Fischer, with his work on carbohydrates, proteins and purines, of Richard Willstätter on the natural colouring matters and enzymes, and many others. This trend has become continually more evident since those days and the field of what might be loosely termed natural product chemistry has been and remains one of the great spearheads of the subject. From it have come many of the spectacular successes of organic chemistry in the past quarter of a century and, in association with the work of biochemists and others, it has driven steadily forward from sugars and alkaloids, through vitamins and hormones, until, with the related branches of chemotherapy, it bids fair to dominate medical and biological studies. Just as it was the perfection of synthetic methods which made possible the initial return to the natural product field, it is equally true that the major forward leaps in their study since 1900 have been associated with the development of analytical methods. Notable among these have been : (1) the development of microanalytical methods, both quantitative and qualitative, which have enabled organic chemists to determine the molecular constitution of compounds of natural origin when they had at their disposal little more material than would in the old days have sufficed for a carbon-hydrogen analysis ; (2) the introduction of the refined adsorption techniques of chromatography, partition chromatography, including paper chromatography and ion-exchange chromatography ; (3) the introduction of physical methods such as absorption spectroscopy (ultraviolet and infra-red) and *X*-ray crystallography as new diagnostic tools together with many others. In this section of the subject at least, one is reminded of the saying ' Every advance in science is an advance in method.'

Now, although this trend of twentieth-century organic chemistry towards what can be described as its original object has been mentioned first, natural product chemistry is by no means the only advancing front in the subject. In passing to the next striking feature it is necessary first to digress slightly on what might be called the international aspect. In the views here set down I may be at variance with others, but as this lecture presents a personal viewpoint it seems reasonable to put them forward.

As is well known Britain, France and Germany were all making similar contributions to the subject at the beginning of the hundred years under review, but in the next fifty years or so by far the greatest development of organic chemistry occurred in Germany. This was in part due to the fact that German industry took far more readily to organic chemistry than did the British and French and grew mightily, thereby in turn raising the importance of the science and adding to its adherents. Perhaps, too, the building of the vast systematic structure on the Kekulé-Couper basis and the working out of new methods of synthesis and degradation were peculiarly suited to the German temperament. In any event at the beginning of the twentieth century Germany dominated organic chemistry and looking at it then one might have been pardoned for making the claim (which Willstätter actually makes in his autobiography) that it was a German science. But German organic chemistry had its Achilles heel. Strong and confident in themselves the German organic chemists placed too little emphasis on theory and were on the whole unsympathetic towards the young and growing science of physical chemistry. Herein lay a weakness which, although not at first evident, caused it in time to lose ground and to allow other countries to make up much of the leeway. We have seen from the position in 1851 what a mess one can get into if fact too far outstrips theory. German organic chemistry was by 1900 becoming a top-heavy factual structure which made few moves in theory beyond the original postulates. Now mere elaboration and verification of, say, the stereochemical consequences of the Van't Hoff-Le Bel theories soon became rather sterile after initial confirmation was to hand, but out of such work grew a new type of theoretical work—an interpretation of molecular structure and in particular of the mechanism of organic chemical reactions. Developments in this field, which have come through the introduction of electronic concepts of atomic and molecular structure, of wave mechanical theory and new views on

valency derived ultimately from physics by way of physical chemistry have made, and continue to make, a deep impression on the whole face of organic chemistry. Such developments we associate especially with the names of Lapworth, Robinson, Sidgwick, Ingold and Pauling, and they are continually being improved and extended as more precise theoretical concepts are introduced. This steady development of theory is a vital part of organic chemical progress and that it keeps parallel with the experimental side is one of the main sources of strength in the subject and explains why we are unlikely to become bogged down now, as we were a hundred years ago, when this vital parallelism was lacking.

The association of industry with the development of what could be broadly described as synthetic organic chemistry has already been mentioned. This section of the subject, which was by far the most significant between 1850 and 1900, continues of course as the main stream, enriching itself continually by absorption and extension of new ideas and discoveries made in work of the two types already discussed. The extent of work in this field has been greatly increased as a result of the rise of chemical industry to prominence in a number of countries, notably Britain and the United States. The reasons for the varying rate of development of organic chemical industry in various countries cannot be discussed here but it is certainly true that, even if the first artificial or synthetic dyestuff (mauveine) was discovered in this country by Perkin, the possibilities of the discovery were realised and exploited in Germany and by 1914 German organic chemical industry dominated the world. The first world war, however, brought home to this country, and to others, the danger of this situation and since then great chemical industries have arisen here, in the United States, and elsewhere.

It is a hard task to select from the vast range of products produced by the industry and from the equally vast ancillary researches those features which would be generally conceded to be most significant. I think however that one or two points could be made. The industry rose on the basis of coal tar as its raw material and aromatic compounds were its mainstay. During the last quarter of a century we have seen a great increase in our knowledge and use of aliphatic compounds due I think to the growing utilisation of petroleum, natural gas and, most recently, of acetylene as raw materials for the industry. This development in new raw materials and in aliphatic chemistry has been very striking. Secondly one might single out the sensational progress in the application of organic chemistry to the synthesis of drugs, as evidenced by the successes of chemotherapy—the sulfa-drugs, atebrine, paludrine, etc., which have done so much towards the conquest of disease. Thirdly one might choose the development of the synthetic polymers or plastics. This field has not only produced such varied materials as bakelites, nylon, synthetic rubber, perspex, terylene, polythene, silicones, and so on, which have found a multitude of uses, but hand in hand with it have gone investigations of great fundamental interest, touching on the mechanism of polymerisation and the properties and behaviour of macromolecules. Here physical and organic chemistry have found much common ground and the basic unity of the science is further illustrated by the way in which the industrial research worker in plastics finds himself nowadays coming close to his colleague in the more biological aspects of organic chemistry. Both find themselves concerned with the interesting and in many respects peculiar properties of macromolecules—many of them determined as much by molecular size as composition—and together they are finding an interest in that new development of stereochemistry, which deals with the conformation of large molecules and which doubtless plays a major part in determining specificity of biological action.

Such then is a brief account of my picture of organic chemistry during the past hundred years. It is admittedly personal and it is in no sense a complete or detailed review. Nevertheless, the picture it gives is one which leaves me with a feeling of profound faith that we stand on the threshold of still greater things, and that organic chemistry's next hundred years will be at least as fascinating as the last.

# THE TREND OF INORGANIC AND PHYSICAL CHEMISTRY SINCE 1850[1]

by

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CHEMISTRY is a very young science, considerably younger than, for instance, physics. It was only near the end of the eighteenth century that Lavoisier laid the foundation of modern chemistry, and at the beginning progress was comparatively slow; most of the developments took place during the last 100 years, and it is obvious that in the time at my disposal I can only touch on a few of the most important features. I think I shall be justified in confining myself principally to the development of two of the fundamental conceptions of chemistry, those of 'element' and 'atom.'

How much did a university student of chemistry hear about elements and atoms in 1850, if he had the privilege of listening to a really competent teacher? We can answer this question very accurately, as luckily the notes taken by a very gifted student during such lectures have been preserved. Perhaps the most famous chemist of those days was Justus von Liebig and his lecture course on 'Experimental Chemistry,' delivered at Giessen until 1852, was taken down nearly verbally by a pupil destined to obtain almost equal fame—August Kekulé. From his lecture notes we can see that Liebig dealt with a greater number of elements than were known in Lavoisier's days—61 instead of some 40—but he did not go any deeper into the question of their mutual relationship, and hardly mentioned the atomic theory, although about forty years had elapsed since John Dalton's ideas had been promulgated by Thomas Thomson, and sixty years since William Higgins had for the first time coupled atomistic conceptions with Lavoisier's chemistry. All Liebig had to say was :—

'For this doctrine of equivalents some explanation can be given by the atomic theory which, although being only something conceived, a hypothesis, is so far the only explanation. One assumes: each body consists of indivisible particles of equal size which, infinitely small, rest at infinitely small distance. If one assumes further that 1 atom of a body unites with 1 atom, or with 2 or 3 of another, the ratios of combination explain themselves. The equivalents are then the ratios of the weights of the atoms. For instance

| H | | O | | Cl | | S |
|---|---|---|---|---|---|---|
| 1 | : | 8 | : | 35·4 | : | 16 |

With one metal atom 1 or 2 or 3 atoms of 0 combine; this explains at the same time the law of multiples.'

These few lines were apparently all a student of chemistry was supposed to know about this 'hypothesis' 100 years ago.

Liebig's indifference to the atomic theory was not a peculiarity of his own. It did not greatly interest any of the leading chemists, because it had made so little progress during the half century of its existence. Neither Higgins nor Dalton nor the chemists of the following generation had succeeded in establishing the relative values of the atomic weights with any degree of certainty, although Avogadro's hypothesis, published in 1811, could have provided the solution; but physics and chemistry were still quite separate sciences and even a chemist of the order of Liebig did not feel the necessity of choosing the atomic weights in conformity with the physicists' ideas; after performing in his lecture the combination of two volumes of hydrogen with one of oxygen he wrote the formula of water HO. Even a decade after Kekulé had studied

[1] Paper read to the Chemistry Section at Edinburgh on August 9, 1951.

under Liebig, in the question of atomic weights there was still complete ' anarchy,' to use Wurtz's expression. In 1860, on Kekulé's suggestion, a meeting of the best-known chemists from many countries took place in Karlsruhe, in which an attempt was made to come to an agreement, but without immediate success. However, the Italian chemist, Cannizzaro, gave to some visitors of the congress, amongst them the German Lothar Meyer and the Russian Mendeleef, a little printed pamphlet, from which they learned the superiority of Avogadro's method of calculating atomic weights. Within a few years these corrected atomic weights enabled them to discover the relationships between the chemical elements embodied in the so-called Periodic Law. Its importance and its most impressive service, the prediction of undiscovered elements, is too well known to need repetition. This prophesying is usually credited to Mendeleef, but actually the English chemist Newlands who—also using Cannizzaro's atomic weights—was the first to draft a table with the main features of the periodic system, had already foreseen an element between silicon and tin, as is clearly indicated on one of his tables. In Mendeleef's table there were gaps not only for this ekasilicon (germanium) but also for eka-boron (scandium) and eka-aluminium (gallium). On the other hand it indicated that 19 elements should find their place between barium and tantalum and foreshadowed even a few trans-uranium elements, as homologues of the lower ones in the same groups. As we know now, these predictions came only very partially true.

Newland's publications on the periodic system date from 1863 to 1866, Mendeleef's and Lothar Meyer's from 1869 and 1870. In 1887 the British Association for the Advancement of Science held a very remarkable meeting at Manchester, coinciding with the Golden Jubilee of Queen Victoria. It was especially memorable for chemists, as the President of the Association was one of their ranks, the professor of chemistry at Manchester University, Sir Henry Roscoe. When in his presidential address he gave a survey of the development of chemistry during the past 50 years, he spoke to an audience which, among other famous foreign chemists, included Mendeleef and Lothar Meyer. He referred to their share in the discovery of the Periodic System in the following words :—

> ' Germany, in the person of Lothar Meyer, keeps, as it is wont to do, strictly within the limits of known facts. Russia, in the person of Mendeleef, being of a somewhat more imaginative nature, not only seizes the facts, which are proved, but ventures upon prophecy.'

This Manchester session of the British Association was the only time when Mendeleef and Lothar Meyer met. This happy occasion was celebrated by a group picture, including also Roscoe, which does not seem to be much known in this country. A copy of it was given to me by Lothar Meyer's son, when in 1930 a meeting was held to commemorate the centenary of his father's birth, and we may perhaps take a quick glance at this interesting group (Figure 1, page 401). Newlands apparently did not attend the Manchester gathering but in the same year was honoured by the Royal Society by the award of the Davy medal—somewhat belatedly, as the same honour had been bestowed five years earlier on Lothar Meyer and Mendeleef.

Roscoe's characterisation of the relative merits of Mendeleef and Lothar Meyer is, I think, somewhat over-simplified. It is true that Meyer, as he himself said later, had been lacking in courage to predict the properties of undiscovered elements, but in another respect he was even more daring than Mendeleef and certainly had the deeper insight. While Mendeleef emphatically denied that the Periodic System indicated any genetic relationship of the chemical elements Meyer saw clearly that it was a strong argument in favour of the assumption of some kind of primordial matter.

However, in those days no more could be said about the deeper meaning of the Periodic System, although many chemists tried to go beyond Lothar Meyer and, by rearranging the tables or curves in all imaginable ways, hoped to discover more about the secret of the relationship of the elements. All these frantic attempts proved to be scientifically completely sterile. Whoever is interested in them

may find a comprehensive survey in a historically very valuable little book published by the Russian Academy of Sciences in 1934 on the occasion of the centenary celebration of Mendeleef's birth. One of the figures, showing the elements arranged in a three-dimensional spiral, has perhaps some topical interest, as, unfortunately, it has been resuscitated from well-deserved oblivion for this year's (1951) Festival of Britain in the South Bank Science Exhibition in London, embellished, it is true, with coloured electric lamps which go on and off. It is undeniably a pretty sight, but would be more appropriately housed in the neighbouring Fun Fair of Battersea Park than under the Dome of Discovery.

In studying these various representations one is frequently afraid that the authors did not quite realise that a curve connecting the elements must never give the impression of any continuity in the Periodic System. The chemical elements are distinct individualities which can occupy only separate points. A continuous line drawn from point to point, as for instance Lothar Meyer's famous atomic volume curve, is useful in bringing out very clearly the periodicity in the position of the points, but has no other meaning. Such a simple and straightforward arrangement of the elements on the abscissa, and of the chosen property of the ordinate, later enabled Moseley to show in a convincing way the strict dependence of the characteristic X-rays of the chemical elements on their ordinal numbers, and to clear up definitely the question as to the number and position of undiscovered elements. Figure 2 (page 402) shows you a table of the Periodic System as it was drawn after Moseley's fundamental work, leaving only six gaps for undiscovered elements between hydrogen and uranium.

This reference to Moseley brings us to the period when, from entirely different quarters, chemistry received decisive help in the understanding of the nature of the chemical elements and of the foundation of the Periodic System. In 1896 Becquerel discovered the phenomenon of radioactivity, in 1898 Pierre and Marie Curie extracted radium from pitchblende, and in 1902 Rutherford and Soddy developed the theory of radioactive disintegration.

These fundamental steps were followed by a wealth of other new and revolutionary observations. Of special importance for chemistry was the recognition of the following three facts :—

(1) Chemical elements are not immutable.
(2) Atoms are complicated structures containing a tremendous store of energy.
(3) Atomic weights are not fundamental constants. Atoms of different weight may belong to the same chemical element, and atoms of the same weight to different elements. They are called ' isotopes ' and ' isobars ' respectively.

This very important discovery of the limited significance of the atomic weights has in a sense been implicit in any table of the Periodic System because here—in contradistinction to its representation by curves—the elements were always arranged at equal distances from each other and not according to the actual value of the atomic weights. The first scientist who drew the consequences from this fact was the Swedish physicist Rydberg who, in a paper of 1897, stated with admirable clarity : ' In investigations on the Periodic System not the atomic weights, but the ordinal numbers of the elements have to be used as independent variables.'

Decisive progress in the understanding of the Periodic System could only be made when chemists had freed themselves from their overestimation of the theoretical consequence of atomic weights. To-day it is perhaps a little difficult for the younger generation of chemists to imagine how reluctant 40 years ago were the vast majority of chemists to admit the possibility that different elements could have the same atomic weight.

Since the discovery of the Periodic System the fundamental importance of the atomic weights had been emphasised, indeed over-emphasised. This is probably one of the reasons why Dalton has been so exalted as the founder of the atomic theory and Higgins' obvious priority completely neglected. Higgins'

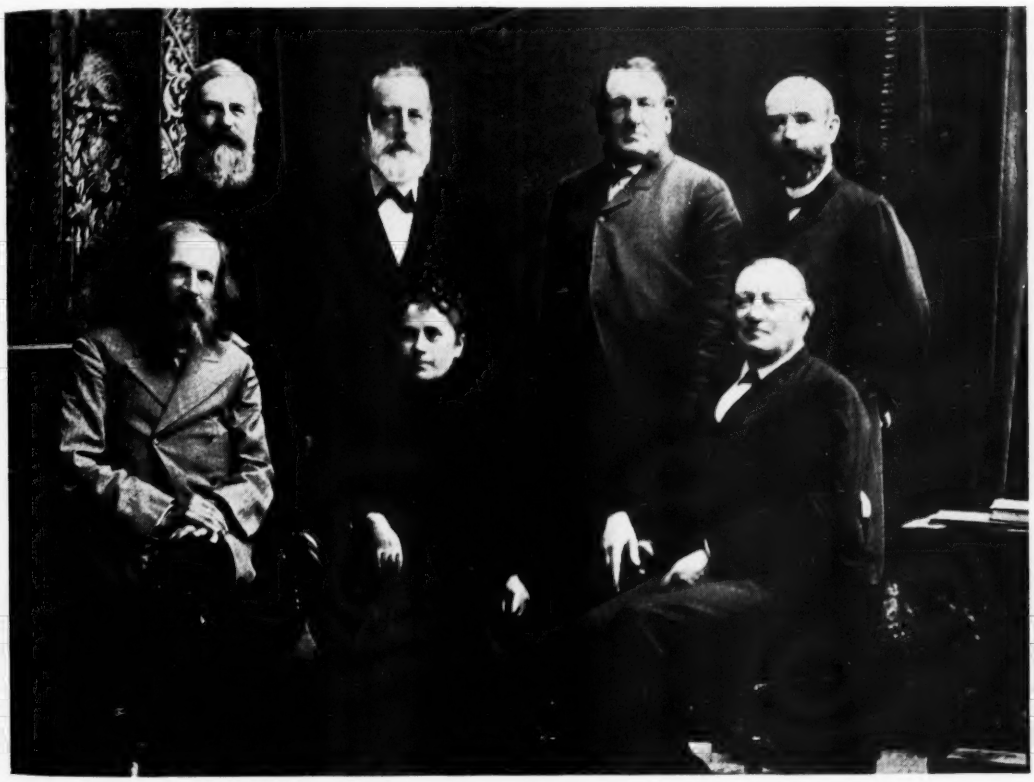
book of 1789 is rare, and it was frequently believed that he had assumed that all atoms have the same weight, while Dalton was supposed to have been the first who had found the truth that each element has a characteristic atomic weight. Such an account of Higgins' views was given by an English historian of chemistry in 1939, and repeated by him in 1948, and again this year; but it is incorrect. Higgins nowhere states as a principle that atoms of different elements have the same weight but only in one or two cases deduces from experimental facts that there was no difference in their weights. When he wrote the formula of water HO, he was perfectly aware that there is a vast difference in the atomic weights of hydrogen and oxygen. (The very competent and careful German historian of chemistry, Hermann Kopp, gave him credit for that.) But when he assumed the formula of sulphur dioxide to be SO, he necessarily came to the conclusion that sulphur and oxygen had the same atomic weight. He suggested equality of atomic weights too in the case of nitrogen and oxygen; that was not at all bad as a first approximation, in order to derive the atomistic constitution of $N_2O$, NO $NO_2$, etc. However, in the second half of the nineteenth century and later it seemed to chemists that anyone who ascribed the same weight to the atoms of oxygen and nitrogen violated the very foundation of the atomic theory. To-day we know of the existence of isobars, and are aware that in the case of the elements oxygen and nitrogen there are actually no less than 4 pairs of them; the 4 nitrogen isotopes $^{14}N$, $^{15}N$, $^{16}N$ and $^{17}N$ are isobaric with the 4 oxygen isotopes $^{14}O$, $^{15}O$, $^{16}O$ and $^{17}O$; so, in the light of our modern knowledge, there is nothing contradictory in Higgins' atomic conceptions, and as his book was published years before Dalton developed his atomic theory the challenge uttered recently by Professor Frederick Soddy to give more credit to the Irish chemist seems only too justified. If we want to denote the chemical atomic theory by a special name, the least we should do would be to call it the Higgins-Dalton theory, and not the Dalton theory.

The experimental results briefly sketched above, and other researches I have not time to mention here, enabled Rutherford and Bohr in the second decade of this century to crown the atomic theory by a theory of the atom and to explain the Periodic System on the lines dimly foreseen by Meyer. I can only mention this great achievement which, I am sure, is so well known that this brief reference will suffice.

The theory of the atom was also able to shed light on the question of the 'chemical forces.' In classical chemistry they were considered as something quite different from the forces dealt with in physics and hardly capable of further explanation. As atoms are now known to be structures built up of electrically charged particles, the combination of atoms to form molecules is to be understood as a consequence of electric forces. All valency bonds are essentially electrostatic in nature although the mechanism of interaction is different in the two cases of electrovalency and covalency. The exact mathematical treatment is difficult except in the simplest cases, but the possibility of explaining in principle all the so-called chemical forces by the laws known to physicists can no longer be doubted. There is still a great amount of hard work to be done by the theoretical physicists if they want to understand in detail the vast accumulated data of classical chemical statics, e.g. the valency of the elements, and we must admire the energy and persistence of those who are working in this field; for it is unusual in theoretical science to see so much labour devoted to studies which can hardly be expected to do more than explain known facts; it seems that this field is almost completely devoid of the most glittering prize of theoretical work, the possibility of predictive discoveries.

The advances made in the understanding of the nature of chemical atoms and of their mutual relationship are by no means only of theoretical interest. The study of naturally occurring radioactive substances was followed by the artificial disruption of stable atoms, by the production of many radioactive isotopes of inactive elements—to-day there are nearly 1,000 different nuclides known—and, most spectacular of all, by the creation of no less than nine chemical elements which are not to be found on our earth and of which one,

FIGURE 1.



*From left to right :—*
*Sitting :* Mendeleef, Mrs. L. Meyer, Roscoe.
*Standing :* Wislicenus, L. Meyer, Atkinson, Quincke.

| Period | Group I a | Group I b | Group II a | Group II b | Group III a | Group III b | Group IV a | Group IV b | Group V a | Group V b | Group VI a | Group VI b | Group VII a | Group VII b | Group VIII | | | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | 1 H *1,008* | | | | | | | | | | | | | | | | | 2 He *4,00* |
| II | 3 Li *6,94* | | 4 Be *9,1* | | 5 B *10,8* | | 6 C *12,00* | | 7 N *14,008* | | 8 O *16,000* | | 9 F *19,00* | | | | | 10 Ne *20,2* |
| III | 11 Na *23,00* | | 12 Mg *24,32* | | 13 Al *27,1* | | 14 Si *28,3* | | 15 P *31,04* | | 16 S *32,07* | | 17 Cl *35,46* | | | | | 18 Ar *39,9* |
| IV | 19 K *39,10* | 29 Cu *63,57* | 20 Ca *40,07* | 30 Zn *65,37* | 21 Sc *45,10* | 31 Ga *69,9* | 22 Ti *48,1* | 32 Ge *72,5* | 23 V *51,0* | 33 As *74,96* | 24 Cr *52,0* | 34 Se *79,2* | 25 Mn *54,93* | 35 Br *79,92* | 26 Fe *55,85* | 27 Co *58,97* | 28 Ni *58,68* | 36 Kr *82,92* |
| V | 37 Rb *85,5* | 47 Ag *107,88* | 38 Sr *87,6* | 48 Cd *112,4* | 39 Y *88,7* | 49 In *114,8* | 40 Zr *90,6* | 50 Sn *118,7* | 41 Nb *93,5* | 51 Sb *120,2* | 42 Mo *96,0* | 52 Te *127,5* | 43— | 53 J *126,92* | 44 Ru *101,7* | 45 Rh *102,9* | 46 Pd *106,7* | 54 X *130,2* |
| VI | 55 Cs *132,8* | 79 Au *197,2* | 56 Ba *137,4* | 80 Hg *200,6* | 57 bis 71 Rare Earths* | 81 Tl *204,4* | 72— | 82 Pb *207,2* | 73 Ta *181,5* | 83 Bi *209,0* | 74 W *184,0* | 84 Po *210* | 75— | 85— | 76 Os *190,9* | 77 Ir *193,1* | 78 Pt *195,2* | 86 Em *222* |
| VII | 87— | | 88 Ra *226,0* | | 89 Ac | | 90 Th *232,1* | | 91 Pa | | 92 U *238,2* | | | | | | | |

* Rare Earths

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VI 57—71 | 57 La *139,0* | 58 Ce *140,25* | 59 Pr *140,9* | 60 Nd *144,3* | 61— | 62 Sm *150,4* | 63 Eu *152,0* | 64 Gd *157,3* | 65 Tb *159,2* | 66 Dy *162,5* | 67 Ho *163,5* | 68 Er *167,7* | 69 Tu *169,4* | 70 Yb *173,5* | 71 Lu *175,0* |

FIGURE 2.

FIGURE 2.

| Period | Group | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| I | | | | | | | | | | | | | | | | | 1 H 1·0080 | 2 He 4·003 |
| II | 3 Li 6·940 | 4 Be 9·02 | | | | | | | | | | | 5 B 10·82 | 6 C 12·010 | 7 N 14·008 | 8 O 16·0000 | 9 F 19·00 | 10 Ne 20·183 |
| III | 11 Na 22·997 | 12 Mg 24·32 | | | | | | | | | | | 13 Al 26·97 | 14 Si 28·06 | 15 P 30·98 | 16 S 32·066 | 17 Cl 35·457 | 18 A 39·944 |
| IV | 19 K 39·096 | 20 Ca 40·08 | 21 Sc 45·10 | 22 Ti 47·90 | 23 V 50·95 | 24 Cr 52·01 | 25 Mn 54·93 | 26 Fe 55·85 | 27 Co 58·94 | 28 Ni 58·69 | 29 Cu 63·54 | 30 Zn 65·38 | 31 Ga 69·72 | 32 Ge 72·60 | 33 As 74·91 | 34 Se 78·96 | 35 Br 79·916 | 36 Kr 83·7 |
| V | 37 Rb 85·48 | 38 Sr 87·63 | 39 Y 88·92 | 40 Zr 91·22 | 41 Nb 92·91 | 42 Mo 95·95 | 43 Tc 99 | 44 Ru 101·7 | 45 Rh 102·91 | 46 Pd 106·7 | 47 Ag 107·880 | 48 Cd 112·41 | 49 In 114·76 | 50 Sn 118·70 | 51 Sb 121·76 | 52 Te 127·61 | 53 I 126·92 | 54 Xe 131·3 |
| VI | 55 Cs 132·91 | 56 Ba 137·36 | 57–71 Rare Earths† | 72 Hf 178·6 | 73 Ta 180·88 | 74 W 183·92 | 75 Re 186·31 | 76 Os 190·2 | 77 Ir 193·1 | 78 Pt 195·23 | 79 Au 197·2 | 80 Hg 200·61 | 81 Tl 204·39 | 82 Pb 207·21 | 83 Bi 209·00 | 84 Po 210 | 85 At 211 | 86 Rn 222 |
| VII | 87 Fr 223 | 88 Ra 226·05 | 89 Ac 227 | 90 Th 232·12 | 91 Pa 231 | 92 U 238·07 | 93 Np 237 | 94 Pu 239 | 95 Am 241 | 96 Cm 242 | 97 Bk 243 | 98 Cf 244 | | | | | | |

† Rare earths

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VI 57–71 | 57 La 138·92 | 58 Ce 140·13 | 59 Pr 140·92 | 60 Nd 144·27 | 61 Pm 147 | 62 Sm 150·43 | 63 Eu 152·0 | 64 Gd 156·9 | 65 Tb 159·2 | 66 Dy 162·46 | 67 Ho 164·90 | 68 Er 167·2 | 69 Tm 169·4 | 70 Yb 173·04 | 71 Lu 174·99 |

FIGURE 3.

plutonium, is one of the most important sources of atomic energy. It will, we hope, not be very long before this artificial element will help to relieve the coal and oil shortage of the world.

There is still some doubt about the best way of placing these newly discovered elements in the table of the Periodic System. Professor Glenn Seaborg, who was the leader of the team which discovered most of the transuranium elements, likes to place the elements from actinium on as a second rare earth group under the lanthanum series. It is felt, however, by other chemists that the discovery of the new transuranium elements does not give any fresh information on the chemistry of the elements up to uranium which are very satisfactorily placed in the usual table of the Periodic System. Figure 3 (page 403) shows the arrangement of the Periodic System which I think does full justice to the present state of our knowledge. If you compare this table with the previous one based on Moseley's work (Figure 2) you will see that the 6 gaps between hydrogen and uranium have been filled, thanks to the discovery of the naturally occurring elements 72, 75 and 87, and to the artificial production of elements 43, 61 and 85; and that the transuranium elements are written in such a way as to make it clear that they are not higher homologues of rhenium etc., but a group of their own, just as the rare earths are, in a different way.

Theoretical chemistry to-day exists only as a part of physics; but that of course does not mean that the physicist can take over the experimental side of chemistry as well. Not only is the whole practical application of chemistry entirely alien to the physicist's training, but also in most purely scientific problems the approach of the chemist is different from that of the physicist and has certainly a value of its own. If the chemist gratefully admits that the deeper understanding of his science is due to the work of the physicist, he can at the same time point out with pride that many of the greatest advances in physics have been made on the basis of chemical discoveries. We have met with an outstanding example, the Periodic System. When, in 1913, Moseley for the first time was able to determine with certainty the number of possible chemical elements between hydrogen and uranium he was astonished to find that almost all of them had already been discovered by the analytical chemists and, as we know to-day, 3 of the 6 missing elements they could not possibly find by any skill as these elements do not exist on our earth. Another similar instance was the discovery of isotopy by Soddy; the conception arose from the proof provided by analytical-chemical work, that some radioactive elements are so similar to each other or to stable elements that they cannot be separated by the usual laboratory methods. Many physicists, including Rutherford, were for some time reluctant to admit that there was something more behind this failure than 'rotten chemistry.'

If we want to add one more example where analytical chemistry paved the way to an important progress in physics we may remember the fission of uranium. It was again mastery of analytical chemistry which led Otto Hahn, and only following him the physicists, to the recognition that an entirely new type of atomic disruption was effected by the impact of neutrons on uranium.

It is to be expected that in future also, in a similar way, the boldness of the chemists—proceeding on evidence of sometimes rather crude chemical experiments—will lead to initial hypotheses which only later are confirmed by more refined physical experiments in a theoretically more straightforward way. One of these developments seems already well under way. Studies on the abundance and weights of the many nuclides known to-day have led to the assumption that there is some periodicity in their internal structure. Further empirical confirmation of this model, especially the rough agreement of the observed spins with expectations derived from it, has overcome the initial theoretical objections of physicists to any such model. To-day the idea of a shell structure is getting more and more to the fore in speculations about the building-up of the nuclei.

Although the experimental methods of chemistry and physics remain different, there is no longer any dividing line between the sciences. Long ago Bunsen used to say 'A chemist who is not a

physicist is nothing' ; now, with equal right, we may say ' A physicist who is not a chemist is nothing.' To-day there is only one fundamental science of the inorganic world, of which chemistry, physical chemistry, chemical physics and physics are just different chapters.

This merging of physics and chemistry has in many ways greatly simplified our general outlook, and it is in my opinion quite unjustified if we hear every now and then complaints that the modern development of theoretical physics has complicated matters. It is true that the chemist is no longer permitted to picture his atoms as solid balls held together by irreducible chemical forces and that, in his theoretical explanations, he, as well as the physicist, has to rely on mathematical symbols which are not capable of representation in space by models taken from macroscopic experience. But was it really true that the old picture was more intelligible ? A little philosophical reasoning shows that the apparent simplicity of the cruder materialistic explanations was quite deceptive ; nobody was ever able really to understand the interaction even between two colliding molecules. This has been shown by the German philosopher Eduard von Hartmann as long ago as 1902 in a very remarkable book, and the still more penetrating studies of modern philosophers about the nature of scientific explanations surely agree with this result. So if to-day there is some complaint about the dry and abstract character of theoretical physics and chemistry, and in comparison the old days of naïve realism appear to some like a paradise, I think we must admit that it was nothing but a fool's paradise which we should be glad to have left at last. We see much more sharply to-day where the boundaries lie for the human mind to any understanding of the world, and our more agnostic outlook should not be considered as a retrograde step compared with the naïve attitude of the nineteenth century.

One point certainly will be admitted by everybody, that the study of inorganic and physical chemistry to-day is at least as fascinating as it was a hundred years ago. Those of us who are approaching the end of the span during which they can hope to take part in scientific research, will sympathise with the words uttered by one of the greatest amongst the French chemists and physicists of that period. Gay-Lussac died in 1850. In his last words he expressed regret to have to go just when science became so curious. ' C'est dommage de s'en aller ; ça commence à devenir drôle.' To-day we have the same feeling, that we are just witnessing a new start, and that with this most interesting period the real fun is just beginning.

# THE DEVELOPMENT OF HISTORICAL GEOGRAPHY IN BRITAIN DURING THE LAST HUNDRED YEARS[1]

by

J. N. L. BAKER

My story begins in 1842 with the publication in Edinburgh of the *System of Universal Geography* (1), edited by James Laurie, and London of Thomas Arnold's *Lectures on Modern History*. The first was an outstanding book, and more than twenty years later was described as ' the most comprehensive and complete volume of its kind now before the English public.' It was a co-operative effort, with contributions from the Professors of Astronomy and Botany in the University of Glasgow, and from the geologist Alexander Rose, of Queen's College, Edinburgh. As the best exposition of political geography, out of which historical geography developed, it has its honoured place.

The Lectures which Arnold gave in Oxford in 1841 and 1842, on the contrary, expressed a revolutionary view of geography. To him geography was one of two kinds—a plan-like geography which was merely a knowledge of the relative position of places and their distances from one another, and a picture geography which was the real geography of a country, bringing out the meaning of its connected parts, and giving point to the location of places. Arnold died prematurely in 1842, but his work was continued by Arthur Penrhyn Stanley and E. A. Freeman. To them, and to their master, historical geography in England owes nearly everything before 1887.

The story therefore takes us mainly to Edinburgh and to Oxford. It falls into three periods—up to 1863, from 1863 to 1887, and after 1887. I have elsewhere dealt to some extent with the Oxford, and the English side of it, and will only briefly mention it here (2). In Oxford Stanley, first as Fellow and Tutor of University College and later as Professor of Ecclesiastical History, was the recognised leader. George Butler, H. F. Tozer and J. R. Green owed much to him. And outside Oxford he secured the co-operation of George Grove, Secretary of the Society of Arts, the body really responsible for the Exhibition of 1851, and later Secretary of the Crystal Palace. This professional engineer learned his geography in the in field, helped Stanley with his *Sinai and Palestine*, wrote innumerable geographical articles for William Smith's *Dictionary of the Bible*, and was, with Stanley, one of the founders of the Association known as the Palestine Exploration Fund. In presenting Grove for the honorary degree of Doctor of Civil Law at Durham in 1875, Professor A. S. Farrer referred to his ' writings in that branch of Biblical learning which related to historical geography ' which ' though they appeared in the modest form of articles in Smith's *Dictionary of the Bible* were in many cases in reality little treatises . . . characterised by that combination of physical and historical inquiry which had marked the gifted German geographer Karl Ritter ' (3). In 1848 Macaulay's *History* appeared with its excellent if limited historical geography in its famous third chapter. Others belonging to this early period were Edwin Guest, Master of Caius College, C. H. Pearson of King's College, London, and Oxford, T. H. Buckle, and William Hughes, who began his career as a producer of maps in 1840.

By comparison Edinburgh figured little. But in 1844 the geologist Robert Chambers produced his *Vestiges of the Natural History*

[1] Paper read before the Section of Geography at Edinburgh, August 10, 1951.

*of Creation*, which, to a small extent, dealt with the subject. To him and to Rose must be added Charles MacLaren, who contributed to the *Elements of Physical and Classical Geography* by James Pillans, published in 1854. Pillans, like Arnold, was a revolutionary. He based his teaching on what he called the ' natural system ' of French scholars, and believed that it was only when physical geography had been mastered that political geography should begin (4).

This development in Edinburgh is of interest not merely because Pillans so closely resembles Arnold, but because Pillans influenced Archibald Geikie. Pillans was Professor of Humanity from 1820 to 1863. Geikie matriculated in 1854. Among those to whom he was indebted were Robert Chambers, Alexander Rose, and James Pillans. Of the last he wrote : ' he was a born educationalist, far in advance of his time in certain departments of teaching, more particularly in his recognition of the place that should be assigned to Geography in the educational system of the country ' (5).

Between 1863 and 1887 there was a remarkable development. Isaac Taylor published his *Words and Places* in 1863. Local names, he argued, may always be regarded as records of the past, ' inviting and rewarding a careful historical interpretation.' The Prospectus of the Palestine Exploration Fund was issued in 1865 with its plea that Palestine should be systematically explored—' The face of the landscape, the climate, the productions, the manners, dress, and modes of life of its inhabitants, differ in so many material respects from those of the Western World, that without an accurate knowledge of them . . . the outward form and complexion of the events and much of the significance of the records must remain obscure.' Pearson's *Historical Maps of England* for the first time discussed period maps. If a single phrase from the Preface can describe the work it is ' reconstruction of early geography.' Tozer's *Geography of Greece* came in 1873. Dedicated to Stanley as the one ' who has done more than any living man to promote the intelligent study of historical Geography,' it is an admirable account of the relations of geography and history. The next year Green's *Short History of the English People* began a series of works from that writer, illustrating his belief that history must be studied in relation to the ground. Later, in 1879, he wrote : ' History strikes its roots in Geography ; for without a clear and vivid realisation of the physical structure of a country the incidents of the life which men have lived in it can have no interest or meaning. Through History again Politics strike their roots in Geography, and many a rash generalisation would have been avoided had political thinkers been trained in a knowledge of the earth they live in ' (6). In 1881 Freeman published his *Historical Geography of Europe*. Many geographers, including Herbertson and Lyde, have wrongly assumed that this book expressed the complete view of Freeman on the subject. Freeman was a disciple of Arnold. He was a careful student of Physical Geography and used it in his writings. In his first lectures as regius professor at Oxford he said : ' The physical construction of any country is no small part of its history ; it is the key to not a little in the political destiny of the land and its folk.' One lecture was devoted to an exposition of his views on the relations of geography and history. ' Geography . . . in its bearings on history . . . has two aspects which, though they often run into one another, are clearly distinct in idea,' he wrote. ' Geography in one of its aspects is simply a branch of history ; in the other it is a precious help to history. In one aspect it is a form of knowledge which may be mastered in the study by books and maps ; in the other it is a matter of travel, a matter of seeing things with your own eyes. The former aspect is that of which I have myself treated in a special work, a thick volume of Historical Geography. . . .' The other aspect, ' the more living study of geography on the very soil of the lands and cities whose history we are studying ' Freeman described as ' making out all that one could make out as to the physical look ' of an area and ' the light which that physical look throws on its history ' (7). In 1886 James Bryce gave his famous lecture to the Royal Geographical Society on *Geography in its relations to History*. Finally, in 1887, came the introductory volume to the *Historical*

*Geography of the British Colonies* by Charles Lucas, and the beginnings of Mackinder's work as Reader in Geography at Oxford.

One figure, that of the geographer William Hughes, stands apart. In 1862 he had published his *Geography of British History*, the sub-title of which, 'A Geographical description of the British Islands at successive periods from the earliest times to the present day' gives some idea of its contents (8). His many manuals and handbooks taught the doctrine, later developed by Mackinder, that physical geography was the foundation of all geographical study but not the end of it. In a lecture at Birkbeck College in 1870 on *Geography in its relation to History* he said: 'The statesman and the warrior are alike students of Geography or, in the absence of such study, find their schemes miscarry, from neglect of some essential element in the problem at issue, depending on circumstances of physical contour, climate, or allied conditions. And the conditions of nature . . . are so infinitely varied as to impart endless diversity to the forms of action by which the outer world manifests its influence upon the course of events.' Hughes never ceased to proclaim the unity of geography. He ended his academic career as Professor at King's College, London, and died in 1876.

We must must now go back to Scotland. During this second period William Cunningham, Henry Drummond, George Adam Smith, George Goudie Chisholm, and Hugh Robert Mill matriculated at Edinburgh while William Mitchell Ramsay, born in 1851, had been at Aberdeen before going to Oxford. Cunningham went on to Cambridge, and produced, in 1882, the first edition of his *Growth of English Industry and Commerce*. It was primarily an Economic History but it shows an appreciation of geography. What later writers, and incidentally historical geography, owed to him may be judged from the works of John Clapham and Lilian Knowles.

Archibald Geikie's lecture on *The Geological influences which have affected the course of British history*, in 1881, was followed in 1885 by A. C. Ramsay's volume on Europe in *Stanford's Compendium of Geography and Travel* in which Chisholm had a small share. In 1886 W. M. Ramsay read his paper on the *Historical Geography of Asia Minor* to the Aberdeen branch of the Royal Scottish Geographical Society (9) and gave his first lessons in geography to D. G. Hogarth. In the same year Ramsay left Oxford for the regius chair of Humanity at Aberdeen, and Chisholm produced his small *School Geography* in which he acknowledges his debt to J. R. Green. This book points to his own later studies on the historical geography of towns. In 1887 came three important contributions from Geikie. In March he lectured to the Junior Scientific Club at Oxford. This lecture, later published as *Landscape in History*, dealt with what he called 'four obvious sources of information regarding former conditions of the land—historical documents, place-names, tradition, and geological evidence.' The same argument was developed in his small book *Teaching of Geography* and, in a particular case, in the chapters which he added to the second edition of his *Scenery of Scotland*.

As in England there was one geographer playing a lone hand. Keith Johnston had edited, in 1876, a new edition of T. Milner's *Universal Geography* and had introduced a long section on historical geography. This reappeared, four years later, in his *Physical, Historical, Political, and Descriptive Geography*, and was reprinted as a separate work in 1909. Johnston's ideas of historical geography differed from those whose names have been mentioned and are not generally accepted. Yet strangely enough Milner's book had opened with a quotation from Arnold's Lecture of 1842.

At the end of this second period we may review what had been done. Almost all writers had insisted that historical geography must be based on physical geography, and had gone to the right sources for that geography, that is to say to the geologists. Arnold learnt it from Buckland, Pillans from Maclaren, Butler and Green from Phillips. Green's contemporary, Boyd Dawkins, helped both Green and Freeman. Pearson quoted Phillips, de la Beche and Geikie. It was Green who brought to the notice of historians Topley's famous paper on the lay-out of Wealden parishes. And in some small measure this Association may claim credit. Stanley and Green at least attended some

of its meetings, and by a strange coincidence Green and Chambers met at Oxford in 1860, when Green heard the elderly geologist 'chuckle at the episcopal defeat.' Further, all writers insisted on the value of the subsidiary evidence of archaeology and place-names, and attempted to make the historical map mean something whether by reconstructing the physical geography of the past or by dealing with selected periods of history. Thus the objects for which Arnold and Pillans had worked had been largely attained.

After 1887 geographers naturally play an increasing part. Mackinder's lectures at Oxford, which did so much to stimulate others, followed an old tradition and were characterised not so much by originality of ideas as by brilliance of exposition. And it is clear from his *Britain and the British Seas* how much he owed, for example, to J. R. Green and C. H. Pearson. After the establishment of the Oxford School, contributions were so numerous that it is impossible even to catalogue them—Hogarth, Haverfield, Grundy, M. S. Thompson, A. J. Toynbee, and A. R. Monroe among ancient historians; York Powell, Arthur Johnson, Charles Oman, C. R. Beazley, and Grant Robertson among modern historians. There was also the 'converted climber,' as Freeman called him, W. A. B. Coolidge. It was through Haverfield that John Linton Myres came back to Oxford in 1895. His influence on Oxford Geography has been considerable. It is a privilege as well as a pleasure to acknowledge, before an audience of the British Association, to which he gave such long service, the debt which Historical Geography owes to him. This paper, too, has greatly benefited from his advice.

Before leaving Oxford, reference must be made to a remarkable series of Lectures organised by Herbertson in 1906. Five historians—Haverfield, Stevenson, Davis, Fisher, and Firth—and Mackinder, took part. Each dealt with a period of history. Only the lecture of Haverfield has been published. One extract from this is of historical interest. 'To most of us the term Historical Geography probably suggests nothing very precise. We are aware that it somehow concerns history and maps, and we have a comforting feeling that it is "up to date." But we do not try to define it. It seems however to have two distinct senses. To the authors of ordinary historical atlases it implies a list of political boundaries, arranged chronologically, and described pictorially on a series of varicoloured sheets. This is certainly useful enough in its way. But it hardly deserves so fine sounding a name as "historical geography." There are others who take a different view and, as I think, a wider and a wiser view. If we would understand the relations of geography and history, we must (they tell us) begin by studying the physical features of the world by themselves, neglecting for the moment all historical or political divisions. We may then proceed to deduce the influence of these physical features in any special period with which we are occupied' (10). He went on to say that he would adopt the second point of view, bringing 'into relief those facts of British Geography which are known to have been of real consequence in Roman times.' Haverfield was doubtless influenced by views expressed by Herbertson in 1904, but his main argument had been used long ago by Arnold and by Pillans, and twenty years previously by Freeman.

The Oxford School was responsible for stimulating a number of works by others. One, for many years the only substantial Geography of Ireland, published in 1911, contained three chapters on historical geography (11). In a later work, *The World About Us*, the same author, ended with a chapter on Environment and History. He quoted two passages dealing with the same historical event, one of which he described as 'a skeleton,' the other 'clothes the bones.' The moral he drew was: 'Seek the geographical environment and you will endow your figures with life and your picture with colour.' The passage quoted with approval came from H. B. George's book *Relations of Geography and History*, published in 1901. The judgment might well have been that of Arnold. It was, in fact, that of Dr. Howarth, the President of our Section, who thus joined a distinguished company. He added to his claims by editing a fifth edition of George's book in 1924.

Apart from Mackinder and Chisholm, historical geography in London begins

with Lyde who made his particular version of it an expression of his personality. It peeps through the pages of his *Continent of Europe* and lies open in his *Peninsular Europe*. ' Our precise need ' he wrote in 1931, ' is to recognise the geographical features and factors behind the political or historic " record "—with a view to interpreting them. Such a book as Freeman's *Historical Geography*, like all Historical Atlases which gave no physical features, is simply a record ; and as such it has—from the narrowest geographical standpoint—not very much more value than a record of what Queen Elizabeth had for breakfast on January 16th some 300 years ago, or what Princess Elizabeth had this morning ' (12). Many found Lyde's teaching stimulating, including Vaughan Cornish. And it may be recalled that Chisholm described Vaughan Cornish's *Great Capitals* as a ' treasure ' not merely for its content but also because ' Geographers will there find a bracing study in being forced to face difficulties that have to be faced in a thorough study of the subject.'

Very different were the contributions of Hilda Ormsby, a disciple of Mackinder, and of Rodwell Jones. *London on the Thames*, *North America*, and *The Geography of London River*, have their assured place in Geographical literature.

At Cambridge historical geography at first followed a distinctive course. Both Guillemard and Yule Oldham were particularly interested in geographical exploration, and the Cambridge Geographical Series, which the former edited, included well-known works by Tozer and Heawood. But it also included Le Strange's *Lands of the Eastern Caliphate*, and *Maguire's Military Geography*. After the establishment of the Tripos in 1918 historical geography took a more normal form, and beginning under B. L. Manning a school of great importance developed. It is superfluous to comment on its products which are well known to all.

So once again we come back to Scotland. The first substantial contribution to the new age of geography came from Chisholm, whose *Commercial Geography*, published in 1889, is strongly historical in character. Eight years later Chisholm contributed two papers to the ' Geographical Journal ' on *The distribution of Towns and Villages in England*. ' The subject of which I propose to treat ' he wrote ' has points of interest under two aspects—first with the physical features of the country, and second with reference to historical conditions. These two aspects cannot be kept wholly distinct, for at all times physical conditions have to be taken into consideration, and in various ways historical development gives at different times a different value to physical features.' These points were more fully developed in the second volume of *Stanford's Compendium of Geography and Travel*, dealing with Europe, which Chisholm re-wrote in 1902. This contribution to the historical geography of the British Isles is little known. In 1908 Chisholm came back to Edinburgh and in his inaugural lecture declared : ' It is anthropogeography that I will endeavour to present to you to the best of my ability . . . our business is to estimate the value for man of local conditions and place relations, to take into consideration all that affects such values '; and, in defence of his position, he added ' it is not among economists and historians that such studies are discouraged, but rather among them that geography, specifically anthropogeography, as a separate branch of study finds some of its most ardent supporters.' It is a happy coincidence that the Preface to Dr. O'Dell's *Historical Geography of the Shetland Islands* (1939) is dated from Birkbeck College, and that the author (13) of *An Historical Geography of Europe* (1935) now holds the chair of Geography in that College where Chisholm spent his early years of academic teaching and from which his first work in historical geography came.

George Adam Smith's *Historical Geography of the Holy Land* was published in 1894. Dedicated to his father, one of the founders of the Scottish Geographical Society, and the author of a *Geography of India*, it came from many years of research, and from two visits to Palestine. It reached its twenty-fifth edition in 1931. Its Preface, and its contents, show that Smith had a true appreciation of the picture geography of Arnold. And to increase its value, and heighten its colour, an atlas was planned. This did not appear until 1915 but it, too, is a magnificent book, the finest historical atlas that has been produced in this country. Smith's *Jerusalem*, in a sense a

supplement to his earlier work, forms the third of a series of books which has few rivals in the field of historical geography. And no small part of their value derives from the splendid maps of John George Bartholomew. A quotation from Smith, which I have not identified, appears on the title page of Mr. W. R. Kermack's *Historical Geography of Scotland*, first published in 1913 and still the only work dealing with this country as a whole.

Last in the story comes Marion Newbigin, a daughter of Edinburgh by adoption. Few geographers had such a range as hers. Though not a trained historian she had the scholar's eye for the significant facts of history, and her books, notably *Mediterranean Lands* of 1924 and *Canada* of 1926, show this admirably. The first she modestly called 'an introduction to human and historical geography': the purpose of the second was 'to show, within a definitely limited period of time and area of space, how historical events are moulded by the framework within which they occurred.'

Thus the story ends, where it began, in this city of Edinburgh. Much has of necessity been left out, and much inadequately treated. If in this treatment I have given prominence to Oxford I hope I have not shown bias. And I do not forget what Oxford owed to Edinburgh. Without in any way detracting from the work of Mackinder I think it is true to say that more was contributed to the Oxford school by Herbertson and Dickson. And here it is appropriate to recall that while still in Edinburgh Herbertson held a research studentship awarded by the Commissioners of the Exhibition of 1851.

It remains to draw some conclusions. Historical geography has a long tradition of the necessary connection between it and physical geography. There is no reason why that tradition should be broken. The modern historical geographer cannot neglect physical geography: indeed if he calls his subject 'the regional geography of the past' he cannot escape it. And, as Mr. Gilbert, the author of that phrase, has pointed out, it follows inevitably that historical geography is one of the bases of proper regional geography.

Few writers, and those only in very modern times, have ventured to define historical geography. The purpose of the majority has been to show the relations between geography and history, a topic now out of fashion. Yet I believe it is the proper function of historical geography. Long ago Arnold and Pillans protested at the separation of physical and political geography. There is a danger in our new specialism that we may be reversing the progress which these early writers made in securing the unity of the subject. Only if that specialism enables us to draw useful conclusions about the geography of man will it justify its inclusion in geography: otherwise it will become, what Freeman called that older plan-like geography, 'simply a branch of history.'

I end with a story originating in Edinburgh and not irrelevant to this paper. While Macaulay represented this city in the House of Commons he came here to open a large public library and lecturing institution. In the course of an eloquent speech he said:—'The knowledge of geography which entitled Strabo to be called the Prince of Geographers would now be considered mere shallowness on the part of a girl at a boarding school.' To this Professor J. D. Forbes replied: 'The contrary is the fact: the knowledge of Strabo was a profound knowledge of geography and it produced the effects of profound and well directed knowledge—it was a knowledge ever increasing, yet ever tempered by the conviction of ignorance; a knowledge which taught his contemporaries to enlarge their acquaintance with the common family of man, to extend commerce, and to preserve human life. Whereas the knowledge of the boarding-school, unless it be tempered with more humility than can be possibly looked for whilst such comparisons are uttered by men of talent on such occasions, will begin in ostentatious displays of memory and end in pedantry and conceit' (14).

## Notes

(1) This work was based on the English translation of C. Malte-Brun's *Précis de la Géographie Universelle* (Paris, 1812–29: E. T. Edinburgh, 1822–31), and on the second edition of A. Balbi's *Abrégé de Géographie* (Paris, 1834). But 'it was not so much an abridgement of these two celebrated Geographers, as an entirely new work' (Preface,

p. v). The commendation of this work is from H. G. Bohn, *A Pictorial Handbook of Modern Geography*, London, 1865, Preface, p. iv.

(2) *The Last Hundred Years of Historical Geography*, History, New Series XXI, pp. 193–207 (1936); and *Mary Somerville and Geography in England*, Geog. J., cxi, pp. 207–222 (1948).

(3) C. L. Graves, *Life and Letters of Sir George Grove*, (1903), pp. 212–13.

(4) Pillans wrote; 'in studying the geography of any country the first thing to be done after settling its boundaries, its length and breadth, and its latitude and longitude, is to acquire a knowledge of its physical characters . . . [only when this has been done] the attention of the pupil ought to be called to the partition of the territory into provinces, circles, principalities, and shires, which are purely arbitrary and have no natural character, no physical reality or assured permanence. With the contents and limits of these civil divisions, which time and conquest are constantly altering, it is no doubt important to be well acquainted, on account of their connection both with the history of past times and the concerns of the present; but even these divisions are most readily acquired and most firmly retained, when the physical geography of the country has been previously mastered' (Preface, xxvi, xxxii). *Cf.* Arnold, *op. cit.*, 127. 'Let me once understand the real geography of a country . . . and then the position of man's dwellings . . . becomes at once easily remembered, and lively and intelligible besides.'

(5) *Scottish Reminiscences*, p. 173.

(6) *A Short Geography of the British Islands*, Preface, p. xi.

(7) *The Methods of Historical Study*, 1886, pp. 296, 297, 312, 313.

(8) 'Those who have been accustomed to work at geography in its historical aspects, whether with reference to the countries of antiquity or to those of later times, will be at no loss to comprehend the sense in which the phrase "Geography of British History" is used by the writer. A glance at the contents of the earlier half of his volume will more particularly indicate the way in which the subject has presented itself to this view. By the geography of history, the writer understands not only what is universally admitted, at least in theory, to constitute the basis of all historical study—viz. a description of the natural features, climate, and productions of a country; but, in addition, some account of its race (or races) of people, of their place in the family of nations, and of the successive stages by which they have advanced towards the position at which their proper history as a distinct nation begins. To these subjects he adds a commentary (geographical in its main features and purposes) on such external events as require reference to the map for their full comprehension, and an adequate appreciation of which is admittedly necessary, not merely for the sake of the facts themselves, but from their place in the record of those changes, social and political, which belong to the higher aims of history. With these latter, the writer does not appear to interfere; he seems only to cast on them such light as geography—using the word in its highest sense—may hope to supply. The distribution of population and industrial pursuits, the foreign and internal trade of a nation, and the characteristic conditions of its manufacturing and commercial industry may be claimed as constituting a portion of his subject so regarded' (Preface to W. Hughes, *The Geography of British History 1862*, New ed. 1866, pp. v, vi).

(9) *The Historical Geography of Asia Minor*, Prolegomena, footnote. The paper was never published and the MS. was lost. The book appeared in 1890.

(10) *The Roman Occupation of Britain*, revised by G. MacDonald, 1924. Lecture II, 'The Geography of Britain and the Roman Conquest,' pp. 89, 90.

(11) *A Geography of Ireland*, by O. J. R. Howarth (1911), chapters XXI–XXIII. Dr. Howarth's *The World About Us* was published in 1922.

(12) *Peninsular Europe* (1931), p. 280.

(13) Professor G. East.

(14) J. C. Shairp, P. G. Tait, and A. Adams-Reilley, *Life and Letters of James David Forbes*, (1873), pp. 193–4. This story was published by Forbes in *The Danger of Superficial Knowledge*, 1849.

# MAMMALS AND FORESTRY[1]

by

DR. F. FRASER DARLING

IT is no exaggeration to say that the relation of mammals to forest growth is a critical one, critical for its survival or for its extinction. This relation of mammals to forests is one of the most dramatic complexes in nature, and action becomes the more dramatic with the advent of man, agricultural man, pastoral man, seafaring man, technological and civilised man. Indeed, the ecological situation rises to the sublime pathos of Greek tragedy, the great quality of which is its inexorability, its known end, the fruitless nobility of those who would prevent the tragedy. We too see the end of our drama and even those of us who are pessimists will continue to try to prevent it. The scientific pessimist will always remember that man is fallible and that pessimism is no excuse for giving up the fight for conservation. The analogy breaks down in that the tragedy is not the bow to the will of the gods but to man's own foolishness or greed.

Forests are either ecological climaxes or stages well on the way to the climax, and a feature of ecological succession is the increasing variety of organic forms, and the degree of stability of the complex. The relative stability of the climax may be interpreted as self-regulation and the biological system becomes a continuum. This theoretical presentation should not lead us to the academic view of the absoluteness of the climax. In nature climaxes are constantly being broken by catastrophes, but these natural factors are limited in their single areas of action and the setback in ecological succession creates edge effects and allows the continued existence of forms which could not endure in the absolute climax. The over-all biological picture is enriched by periodic natural catastrophe.

[1] Paper read at a joint Session of the Section of Zoology and the Sub-section of Forestry at Edinburgh on August 13, 1951.

The profound and benign influence of mammals in this natural chequerboard of climax forest, succession forest, secondary growth, primary colonisation, and areas devastated by fire, hurricane and vulcanism, will be clearer if we classify the animals according to what they do. There are four great groups—predators, grazers and browsers, rodents and insectivores. Very broadly, the predators and insectivores favour forest growth, and the rodents and grazers and browsers depress it, but we should be wrong to accept completely such a generalisation, for most of those animals which depress forest growth also act in ways which advance it so long as a certain density is not exceeded. The great insurance against over-density of the gnawing-grazing-browsing animals is the predatory complex, and the insectivorous mammalian group shares with some birds and the predatory and parasitic insects the control of a broad stratum of invertebrate life. Control is never absolute, of course, and no one species is critical; it is the complex as a whole which is the insurance company. There is a diastole and systole in this dynamic rhythm, but in nature the continuum is real and energy conserving.

If we imagine British forests of, say, the Saxon period, our predatory complex consisted of ten species—wolf, brown bear, wild boar, marten, wild cat, polecat, fox, badger, stoat and weasel. The first three of these are extinct in this country; the next three are extinct in England; the marten and polecat are so far reduced in Scotland and Wales as to be insignificant; only the last four exist as an effective predatory complex over the country as a whole. This mutilated group is left with more niches to fill in control, but it is further handicapped as an insurance company by constant persecution by man who, having renounced his forest ancestors, uses land in other ways and rightly or

wrongly considers that the predators restrict his modes of land use or what he calls the profit from such activities. We may take as examples the entirely foreign land use of hill sheepfarming which finds the fox anathema, and the artificial development of so-called game preservation which presses hard on badger, stoat and weasel. I would go so far as to say that an attempt to maintain forest over a long period of time or to establish new forest on a considerable scale is either likely to fail or will be unduly handicapped if the carnivores and raptors are removed or too heavily reduced.

The wild boar has been included in the predators because it is a consumer of nests of mice found in its ceaseless rooting in the forest floor. Thereafter, its effect may be thought to be depressing on the growth of forest, but not if the density is moderate. Once, in the Forest of Fontainebleau, Dr. Clement Jacquiot explained to me that wild pigs, in their search for pannage, missed and buried that one acorn in a thousand, saving it from winter frost and enabling it to germinate and establish a firm root system. The wolf and the fox were the effective predators on the young pigs. The large herds of domesticated razorback swine of the Saxons were without doubt a major factor in depressing forest regeneration, giving the floor a tilth favouring the growth of grass on which the Saxon put his second line of shock troops, the sheep.

The group of insectivorous mammals in the forest is perhaps most discrete ecologically. The mole has its narrow stratum below the forest floor, helping to circulate the loam and mould, eating both beneficial and harmful invertebrate forms, not being directly preyed upon to any extent and not directly affecting forest growth. The shrews have an even narrower stratum on the forest floor but have great mobility, and because of their metabolic characteristics must hunt insects and other small invertebrates ceaselessly. They are preyed upon only inadvertently. The hedgehog is in effect casual labour at the busy time, for it sleeps in winter. Its effect on small ground-nesting birds and their young has never been accurately determined, but is probably not negligible. The bats feed on the wing and their range of insect prey is therefore a relatively narrow one. The place of bats in forest ecology has still to be determined, I think, but as their influence is a matter mankind could do very little about, it is unlikely that Cheiropteran ecology will be tackled *ad hoc*. Academically, it ought to be done.

The rodents in the Saxon-age forest and on its edges were the beaver, red squirrel, bank-vole, field-vole, wood-mouse and hare. There is one extinction, the beaver, and two introductions have occurred, the rabbit and the grey squirrel. The stratification and niching of the rodents is interesting; hare and rabbit are desert animals which are desert makers, wholly herbivorous and effectively preventing regeneration of woodland when they are numerous. The wood-mouse *Apodemus* is also much more important than many people think; this species is nocturnal and leaves little sign but is much given to nipping through seedling tree shoots. Its toll of germinating acorns is enormous. But it is also insectivorous in part, being a great burrower in the surface leaf-mould for insect larvae and pupae. The field-vole inhabits the newly planted wood or the newly growing one following catastrophe by fire. It is harmful when it reaches a high density, but as Elton and Summerhayes have pointed out, there is a density of field-voles on young plantations which can be beneficial, in that the runs under the thick herbage layer help surface drainage and keep the habitat more open. The squirel inhabits the woodland after it is a few feet high and eats the buds of trees, much reducing their annual potential of photosynthesis and distorting their shape. The squirrel's effect on seed production and seed survival is also depressing, but forgotten caches are possibly to some extent beneficial as they become favourable loci for regeneration. Both squirrels and wood-mice eat eggs and young of small woodland birds which are consumers of defoliating insects. But what is the possible effect of the squirrel on the wood-pigeon? There are aspects of Sciurine ecology yet to be discovered. As Watt pointed out in 1919, if one member of the rodent complex is absent, regeneration may occur, but as a complex

these animals may entirely prevent new growth.

The rodents form the main food supply of the predatory group, but not the whole of it. Badgers, for example, as diggers of rabbits' nests, also feed on larvae and pupae of insects. The fox is catholic in its tastes. Stoats and weasels appear to live almost exclusively on rodents, with young birds in spring. The marten was the most considerable predator on squirrels, but rabbits and birds were included in its diet. The marten was probably the only animal, man included, which could prevent those damaging concentrations of wood-pigeons in young coniferous woodland. This brings us to the point that human ingenuity is not yet clever enough to control small rodents in an extensive habitat. Their vast numbers and fecundity, their smallness, their nocturnal or crepuscular habits and propensity for going underground are too much for us. A good and varied stock of small carnivores and raptors is not only our best insurance but the cheapest.

The grazing and browsing animals of the earlier forest were a small group but represented a considerable bio-mass—elk or moose, red deer, probably fallow deer, roe deer, wild cattle and ponies. But these were large animals whose influences and fate in the forest were bound up with domestications by man. Extinctions have been the elk and the wild cattle. The ponies have disappeared as a wild species but persist in semi-domestication in the New Forest and some degraded forest ground as in Wales and on Exmoor. This desert-plains herbivore is a successful open-forest species if the rainfall is not too high. The red deer has been greatly reduced in numbers except in the Highlands of Scotland where I imagine they were more numerous between 1880 and 1940 than they ever were in the old forest before the extinction of the wolf in 1743. Their influence on forest growth is depressive, but again a certain density may be an advantage. Dr. Jacquiot, taking me one October night to hear the stags roaring in the Forest of Fontainebleau, explained that the estimated herd of 300 in 40,000 acres of forest probably did more good than harm, saving labour in brashing the trees. It is doubtful whether we can endure the red deer in Britain as a forest species just now because our woodlands are too small in area and not sufficiently varied in age and species ; if the Fontainebleau density of 1 : 133 acres is a good figure, we have few forests that would support a sufficient number to fulfil the definite gregarious pattern of this species. Red deer help with the thinning of coniferous woodland if this is extensive enough, but in smaller plantations, their thinning is badly done from our point of view and that of the trees. They use conifers for rubbing and wear away the bark completely ; such ringed trees die and are no longer used, fresh ones being started. Examining an unfenced 10-acre plot of Scots pine in the Highlands, I estimated 10 per cent. of the trees had been killed in this way. The main damage was at the edges of the plantation, so that the area of woodland was shrinking.

Fallow and roe are more completely woodland deer than the red deer. Their influence is depressive, but a light density probably helps in thinning a too bountiful regeneration and in preventing the shrub layer getting too dense for regeneration of forest trees. Where trees are planted—and nobody wishes to plant at a greater density than necessary—the roe kills far too many by rubbing his antlers in the crown of young trees. This brings us to another point, that natural forest as a continuum, being used by man on a selective felling basis, can accommodate these deer with advantage, but the plantation-clearfelling system can scarcely endure them. It is perhaps insufficiently realised that planted trees are sick trees for two or three years and seem to be more palatable to deer, sheep and rabbits than naturally regenerated trees. I suggest that the reason for this phenomenon is that the transplant, inevitably wounded, secretes gums which are manufactured from sucrose marshalled by the plant for this purpose. A transplanted tree is sweeter in the sap until it is well established.

Control of deer in natural forests is done by the larger predators, wolf and fox, the wolf being the only effective predator on adult deer, other than man. The fox takes deer calves and fallow and roe fawns in this country where, with the extinction of the wolf, and because we have no coyote,

the fox reaches into a higher stratum of prey than it does in America.

Deer are beautiful animals with a high degree of popular appeal. They have been scarce enough in England for a couple of hundred years for that appeal to be sentimentally enhanced. But we shoud make up our minds that if our forestry system is not to be that of the continuum and if we are to persist in the hysteria of predator destruction, deer can have very little place in our British woodlands. It is not generally realised how rapidly fallow and roe deer can increase, and how they do increase after periods of heavy felling followed by a lot of secondary growth. We see little of our deer in England and Wales, but the forester knows that they are increasing at the present time and becoming difficult to control. The recent Report of the Committee of Inquiry into Cruelty to Wild Animals has rightly recommended that all snaring of deer should be prohibited, but the forester will lose his easiest means of reducing roe in the absence of predators.

I have recently returned from an extensive tour in the United States where I gave particular attention to this problem. As Leopold has said, there are probably more deer in the United States at present than there have ever been, in history or pre-history, as a result of the vast areas of secondary growth now available, combined with the human pressure on predators and the immense sporting and sentimental interest in deer. Unfortunately, a heavy population of deer is quite incompatible with healthy forest growth as a continuum, but a minority of people can look at forest with open eyes. The presence of trees does not constitute the wholeness of the forest biome. The trees can be there when the forest has in effect gone. I was in the Flag Yard in North Wisconsin where the forest has a distinct browse line and all regeneration of nurse trees such as aspen and hemlock has been checked ; small maples which had been browsed back were infected by a fungus ; so that a whole age-class had been missed, the effect of which will be felt for a long time. Winter starvation deaths are numerous. I also worked over the Kaibab Plateau in Arizona where the floor of the valuable ponderosa pine forest is getting bare and the aspen is browsed hard back because of the increase in the herd of mule deer. A crash in the deer population by starvation is inevitable, but when the crash comes, the immense damage to the environment will have been done.

Some trees, such as aspens, are biological pumps of calcium salts and are indispensable to a healthy forest continuum. They are the hardest hit when deer and other grazing and browsing animals increase unduly. Legumes and grasses also tend to disappear from the field layer of dry areas, especially if domesticated cattle or sheep are allowed to graze in a forest. *Senecio* comes in as an indicator of misuse or, in western America, *Rudbeckia* and *Madia* spread into the bared forest floor. What we should never forget in watching the influence of grazers and browsers in forest, is that the animals are more flexible than the forest. If the forest is hit too hard it will go sick and fail within a century. The deer can stand cutting back and the population is in healthier reproductive state for not being allowed to reach a peak. Control is made the more difficult with the wolf gone from much of America. Britain has developed so far that the wolf is neither necessary nor wanted, but I would maintain that the fox is still necessary in Britain as one of the guardians of forest growth.

As our forests increase we can expect the deer problem to become more urgent and human pressure on fallow and roe deer will be essential. Incomparably the best natural forest I saw in the United States was in the Menominee Indian Reservation in Wisconsin and around Mount Mackay in the Apache Indian Reservation in Arizona. The moral is plain ; the white man with all his gadgetry of sport does not put sufficient pressure on the deer in the very short seasons allowed at this particular moment in history when there are such large areas of secondary growth. The wild-life scientists know this, but so successful was Theodore Roosevelt's propaganda half a century ago, when the forests were but newly felled and deer scarce, that it will take time again to educate people to shoot does. Our own Highland natural woodlands have suffered badly for a century through quite insufficient hind shooting. Forest needs constant

and highly skilled wild-life management and the woodlands of Britain are not getting it.

Finally, the influence of domesticated stock on woodlands must be mentioned. To be short, it is wholly bad. The forest needs its field layer, though I cannot here go into the involved plant and invertebrate ecology to demonstrate the truth of this statement. Cattle and sheep destroy the field layer and effectively prevent regeneration. Goats destroy adult trees by barking them. Cattle also do much treading, which a forest soil and some species of trees cannot endure.

I would suggest in conclusion that in Britain we should overhaul our thinking about land use, wild-life management and certain sporting pursuits which interfere markedly with the wild-life complex. It may be that hill sheepfarming and forestry are incompatible if we go on as we have done. Large sums of money are being dispensed by Government for destruction of predators and more money is being spent killing rodents and fencing against them, all without effort to get down to basic land-use ecology. It is a perfect example of the dog chasing its own tail. The toll of foxes on lambs is a grossly exaggerated one, but I would suggest that Government, forest, and farm land of this country would be better off if present systems of fox control were to cease and a 5 per cent. loss of hill lambs be expected, accepted and paid for by an increased subsidy on hill ewes. (No less mutton would get through to the table!) In the course of the West Highland Survey I have found many striking examples of overstocking with sheep and the consequence of a falling lambing percentage after a few years is invariable. As fox predation on lambs is for a short season only, the foxes would not violently increase because of the presence of lambs. There would obviously always have to be selective pressure on the fox population. Further, small predator control in woodlands in the interests of pheasant shooting should be forbidden.

I admit to being provocative, but let us have some more factual research on wild-life management in the interests of truth, not of increase of a few favoured species or with preconceived notions in our heads. The time has surely passed when to study any animal with a backbone is to damn one's self academically. The wild-life complex is an immanent entity, benign in habitat maintenance if it is in a state of gentle oscillation, but a menace to our own survival if a warped complex begins to oscillate violently and percussively.

# PHYSIOLOGICAL PROBLEMS OF MINING

## REPORT OF A SYMPOSIUM

At the Dundee meeting of the British Association in 1947, the first year of national ownership of the coalmines, four of the thirteen sections discussed various aspects of coal production and utilisation. Of about twenty papers which covered the future of coal supplies, coal as a source of heat and power, and so on, only one dealt with the working conditions of the coalminer. When the Association returned to Scotland for the meeting in Edinburgh, in 1951, the Physiology Section devoted one of its sessions to discussion of physiological problems of mining, and H.R.H. The Duke of Edinburgh, President of the Association, was present for part of the time. The following report contains the substance of the papers.

### The Debt of Physiologists and Miners to J. S. Haldane

by

Dr. R. Passmore.

For another generation at least, coal will be the chief source of our industrial power and so of our prosperity. The miners, who win the coal, have work which is dark, dirty and dangerous, and this is to some extent inevitable. Before the principal speakers discuss the physiological implications for the miners of this darkness, dirt and danger, it is proper to pay a brief tribute to J. S. Haldane, the physiologist who contributed so much to the safety and welfare of miners, especially since we meet in the city in which he was born in 1860 and at whose Academy and University he received his education.

Haldane's greatest contributions to physiology were the discovery of the precise and delicate nature of the control of respiration by carbon dioxide and the development of methods of haemoglobinometry and gas analysis. Academic physiologists will do well to remember that these discoveries, fundamental to our science, were part of the results of Haldane's keen interest in practical mining problems and of many experiments carried out underground. Practical miners should know that Haldane, a constant attender at meetings of the Institute of Mining Engineers, was able to contribute so much to the development of our knowledge of ventilation in mines, of the importance of carbon monoxide poisoning and of new possibilities in rescue work because of his great understanding of theoretical physiology acquired in university laboratories and libraries. He was also deeply interested in problems of vision and dust diseases. His technical contributions to both physiology and mining were great, but most important was his attitude to these two fields of study. In the words of Dr. C. G. Douglas, ' if practical problems influenced his work in physiology it is equally true to say that he made use in turn of the researches in pure science to deal the more successfully with the difficulties and risks which so many have to face in their daily occupations. He drew no sharp distinction between pure and applied science, for they were to him but two aspects of the same thing, acting and reacting one on the other : to Haldane the welfare of mankind was the fulfilment of the growth of knowledge.'

### The Effect of Lighting on the Health and Efficiency of Miners

by

Dr. C. G. Gooding

The development of mine lighting has been hampered by the need to ensure safety from the explosion hazard. For a century after the invention of the Davy Safety Lamp in 1815 the miner, in safety lamp mines, worked in a level of illumination lower than that provided by the candles and other naked lights in general use until that date.

The reasons for this were the inadequate candle-power of the safety lamps and the fact that they had to be placed further from the coal face than the naked lights.

There has, of course, been a constant stream of improvements in safety lamps, but until a quarter of a century ago, in a safety lamp mine, the miner was compelled to exercise his sight without using the most efficient part of his visual screen, which is not designed to function in such dim light.

The introduction of the electric cap lamp in the last 25 years has made it possible for the miner to see in what might be called a normal way, and recent trials of fluorescent fixed lighting at the coal face hold out hope of a further striking improvement in lighting—something like a thousandfold or greater increase of the light given by early safety lamps.

Inadequate lighting in the past, especially at the coal face, has been responsible for the development in a considerable number of mines of the disease miners' nystagmus. This disease, although less common than it was 30 years ago, has resulted in the disablement, for periods of one or more years, of over 14,000 miners in the decade 1938–47.

In some parts of the country, in Scotland for example, the occurrence of disabling disease appears to have been checked. It is not, however, possible to say it has been abolished, since the disease may exist in latent form which may be converted to overt disability in adverse social conditions.

While it is possible with the best lighting available to-day to control miners' nystagmus, it would be a great mistake to think of mine lighting only in its relation to this disease. A number of other benefits are considered likely to result from improved lighting in mines. Two commonly mentioned are improvement, both quantitative and qualitative, in output and increased safety. Some small-scale trials have been followed by a reduction in accident rate and by cleaner coal.

The last to be mentioned, but probably the most important, benefit we might expect is the improvement in physical comfort and psychological temper. A sufficient improvement in lighting could convert mines into underground factories and could work a revolutionary change in the psychological climate of the industry.

Increased comfort is a legitimate aim since this is closely associated with industrial efficiency. The miner's trade has been described as dirty, dangerous and dark. Attempts have been made, with at least partial success, to mitigate the dirt and to reduce the danger. It would be a legitimate aspiration for the industry during the next few years to remove the dark and with it another edge of asperity in the miner's life.

## The Effect of Dust Inhalation on the Working Capacity of Coalminers

by

Dr. C. M. Fletcher

The late Professor J. S. Haldane's conclusion that the effect of the inhalation of coal dust on the health of miners was beneficial was based upon apparently sound arguments but he was led to what must now be admitted to have been a false conclusion. Standardised death rates of coalminers from the Registrar-General's Decennial Supplement from 1900–1930 show that throughout this period elderly coalminers suffered from an excessive mortality from respiratory diseases other than tuberculosis, while miners of all ages showed a relatively low mortality from pulmonary tuberculosis. Haldane concluded that coalminers did not develop silicosis (except for the small number of men who are exposed to pure rock dust in their work as hard-headers or drifters) for workers in all occupations in which there was known to be a risk of silicosis showed a high mortality from pulmonary tuberculosis, especially in the older age groups. The coalminers' high mortality from respiratory diseases other than tuberculosis, Haldane attributed to the development of bronchitis consequent upon continued heavy manual labour.

It is our present conclusion that the high respiratory mortality of coalminers, particularly in South Wales, may be at least in part attributable to the inhalation of large amounts of coal dust and that this inhalation may cause severe respiratory disability, but we still agree with Professor

Haldane that the inhalation of coal dust modifies the effects of pulmonary tuberculosis and that, in some ways, this effect may be beneficial.

The serious effect of coal dust inhalation on the working capacity of miners has become apparent chiefly as the result of the admission of miners to compensation under the provision of the Workmen's Compensation Acts for silicosis at first, and later for pneumoconiosis. There has been a strong predominance of certified cases in South Wales compared with the rest of the country. The great increase in the number certified after the introduction of the Pneumoconiosis Scheme in 1943 was partly attributable to the fact that this scheme admitted to compensation men with earlier radiological abnormalities, but is also attributable to the effect of the Essential Works Order during the war and to increased dustiness in the mines as a result of mechanisation (Fletcher, 1948). During the last few years, the number of cases certified in the rest of Great Britain has been steadily rising whereas in South Wales, the figures are stationary and may even be decreasing. This increase in the rest of Great Britain has chiefly taken place in the Scottish and Southern Divisions of the National Coal Board. The reasons for the great differences in incidence in different parts of the country are not yet fully understood.

Hart and Aslett (1942) showed that the radiological abnormalities which they described as ' pneumoconiosis of coalworkers ' were attributable to the inhalation of coal dust. There can, therefore, be no doubt that the inhalation of coal dust may cause severe loss of working capacity among coalminers ; for all these men certified under the Workmen's Compensation Act and Industrial Injuries Act were certified to be partially or totally disabled by their disease.

Pathological studies of coalminers affected by dust inhalation, especially those of Gough in the Welsh National School of Medicine (Gough, 1947 ; Gough *et al.*, 1949) have shown that at first, coal dust accumulates in and around the respiratory bronchioles where there is a minimal reticulin reaction to its presence. At this stage, called simple pneumoconiosis, the pathological reaction to the coal dust would not be expected to cause any important disturbance of respiratory function. In elderly coal workers, the lung tissue in the neighbourhood of the deposits of coal dust may become broken down to form ' focal emphysema ' (Heppleston, 1949). In uncomplicated pneumoconiosis, this focal emphysema only occasionally reaches proportions severe enough to interfere seriously with respiratory function.

The pathology of simple pneumoconiosis of coalworkers is thus quite different from that of silicosis in which nodules of collagenous fibrosis are characteristic and focal emphysema is less marked.

In many cases of coalworkers' pneumoconiosis, collagenous fibrosis does occur in the deposits of coal dust. Collagenous nodules of rather irregular shape form and later coalesce to form large areas of massive fibrosis which may occupy and distort large areas of lung and must therefore interfere seriously with respiratory function. Associated gross hypertrophy of the right ventricle is commonly found. Belt and Ferris (1942) and more especially Gough (1947 ; 1948) have suggested that this collagenous fibrosis is probably always due to the supervention of tuberculous infection in a lung already affected by simple pneumoconiosis.

Radiological studies enable us to make the same distinction between cases of simple pneumoconiosis and cases with massive fibrosis. In the former, the deposits of coal dust and associated reticulin fibrosis produce disseminated fine opacities throughout both lung fields. A system of classification according to the severity of these opacities, has been produced by the Pneumoconiosis Research Unit and is widely used throughout the country now (Fletcher and others, 1949). A similar classification has been recommended for international use by the International Conference of Experts on Pneumoconiosis held under the auspices of the International Labour Organisation at Sydney, 1950. By this classification, three categories of increasing abnormality are recognised in addition to normal films, normal films being indicated by the figure 0 and the categories of increasing abnormality indicated by the figures 1, 2 and 3. Follow-up studies have shown that progression from the earlier to the

later stages of simple pneumoconiosis occurs only in men exposed to the inhalation of coal dust. After exposure to coal dust has ceased, the disseminated opacities do not increase in profusion.

Localised, larger opacities corresponding to collagenous nodules may also be seen in the radiographs of many cases. Once these have appeared, they tend to progress, regardless of whether or not further dust exposure is continued, to the formation of large massive shadows corresponding to the areas of massive fibrosis described by the pathologists. Four categories of increasing abnormality described by the letters A–D are also described in this condition of progressive massive fibrosis.

The relationship between these radiological abnormalities and the associated physical disability have recently been studied in the Pneumoconiosis Research Unit. The disability in pneumoconiosis is chiefly due to excessive shortness of breath on exertion. The simplest single test for measuring the severity of this breathlessness is the maximum breathing capacity, which expresses the maximum voluntary ventilation of which a patient is capable in litres per minute. The results of this test correlate well with clinical assessments of disability. Since increasing shortness of breath on exertion is also characteristic of increasing age, it is necessary in comparing cases of pneumoconiosis with one another and with normal controls to take careful account of age. An experiment in which this was done showed that serious disability in coalworkers' pneumoconiosis is chiefly due to the presence of massive fibrosis. In simple pneumoconiosis disability is slight.

What is the nature of this massive fibrosis? Pathologists suggest it is the supervention of tuberculous infection on a simple pneumoconiosis. Clinical and epidemiological evidence support this hypothesis. Although during life, we seldom find a positive tuberculous sputum in cases of massive fibrosis (not more than 3 per cent.) ; at post mortem we find a positive culture for tuberulosis in 40 per cent. If the process is tuberculous it is therefore greatly modified. Gardner's dictum was that in pneumoconiosis, the tubercle bacillus is 'locked in its own fibrous prison.' The radiological evidence that massive fibrosis progresses independent of dust exposure also suggests that some factor other than dust is involved. The blood sedimentation rate is usually raised in massive fibrosis but not in cases of simple pneumoconiosis without other infections, and this suggests an infective process. The radiological similarity between massive fibrosis and tuberculosis in the early stages suggests that the infection may be tuberculous. Perhaps the strongest evidence is derived from epidemiological studies carried out by Dr. A. L. Cochrane in the Pneumoconiosis Research Unit.

In the course of field surveys at coalmines in various parts of the country in which over 5,000 radiographs of miners have been taken, Cochrane has not yet observed an example of unmodified reinfection type tuberculosis in a miner who also has evidence of simple pneumoconiosis. The process of cavitation with spread of the infection to the other lung does not seem to occur. On the other hand, among miners with early simple pneumoconiosis there is a high prevalence of apical shadows which look exactly like healed tuberculosis. In the higher categories of simple pneumoconiosis (Mann, 1951) the prevalence of tuberculous shadows falls off, their place being apparently taken by shadows of massive fibrosis.

Our conclusion is, therefore, that the presence of coal dust in the lung modifies tuberculous infection. In the earlier stages of coal dust accumulation, the modification is beneficial resulting in an increased tendency to heal by fibrosis, but when there is more coal dust in the lung, the fibrous reaction is exaggerated and massive fibrosis with its attendant disability results. If our hypothesis is correct, we can explain the abnormal mortality figures of coalminers which misled Haldane by suggesting that the increased number of deaths from respiratory diseases other than tuberculosis include a number of deaths due to pneumoconiosis, many of which are really attributable to a modified form of tuberculosis which would not be recognised as such by the general practitioner signing death certificates, and that the low tuberculous mortality is due partly to the concealment of some tuberculous deaths and partly to the

tendency for tuberculosis to run a mild course in cases of early simple pneumoconiosis.


REFERENCES

COCHRANE, A. L., FLETCHER, C. M., GILSON, J. C. & HUGH-JONES, P. (1951). *Brit. J. Indust. Med.*, **8**, 53.

FLETCHER, C. M. (1948). *B.M.J.*, i. 1015, 1065.

—— MANN, K. J., DAVIES, I., COCHRANE, A. L., GILSON, J. C. & HUGH-JONES, P. (1949). *J. Fac. Radiol.*, **1**, 40.

GOUGH, J. (1947). *Occup. Med.*, **4**, 86.

—— JAMES, W. R. L., WENTWORTH, J. E. (1949). *J. Fac. Radiol.*, **1**, 28.

HART, P. D. & ASLETT E. A. (1942). *Med. Res. Counc. Spec. Rep. Ser.*, No. 243.


## COALMINERS' PNEUMOCONIOSIS

### *Employment Problems of the Disabled*

by

Dr. A. Meikeljohn

WHILE, so far, the main incidence of certified cases has been in South Wales there is evidence that, for various reasons, the number is increasing in the other mining areas. It is not possible to provide satisfactory alternative jobs for these disabled miners. Reluctantly it must be concluded that almost the entire responsibility for the continued employment of pneumoconiotic coalminers must be accepted by and within the industry. The problem is not rehabilitation of disabled coalminers but rehabilitation of unfit coalmines. In this assignment the main burden must fall on the employers and mining engineers, not on doctors and sociologists. There can be no speedy amelioration without the vital co-operation of the men themselves and their unions. This constitutes a challenge to discipline and leadership.

There are several important prerequisites which must be fulfilled. First the whole problem must be extricated from 'politics,' secondly it must be realised that pneumoconiosis of coalminers is not peculiar to South Wales, thirdly the fine focus on disease and compensation must give way to the acceptance that our existing knowledge of the causation of the disease is already adequate, without further research, to make effective prevention possible. Mining engineers in South Wales, by such methods as water infusion, have already made a useful start.

The clamant demand is for more coal—for higher and greater production. To this end more mechanisation and more men to work the machines is the invariable answer. Is it quite certain that in some mines more coal-cutters and longer conveyor belts are not indirectly diminishing output by the deleterious effects on the men? It has almost become trite among doctors to say that pneumoconiosis is an engineering problem. Until the disease is controlled so as not to abridge life or seriously impair health in a normal working span, then the doctor must bear his full part in the team. But in this particular field of mining the doctor is simply an expert adviser; he is not the director in charge of operations. Though the production of dust must be kept to the minimum, considerable dust is unavoidable and the occurrence, and in certain circumstances the progression, of the disease will reflect the extent of the dangerous concentrations of air-borne dust. The doctor has two main duties, first to assist the engineers to locate the dangerous operations and stations and secondly to supervise the health of affected men still at work.

Since 1944 young entrants to the pits have been subject to initial medical examination, but only in South Wales has this statutorily included radiographic examination of the lungs. This valuable scheme must be made uniform throughout Great Britain and extended to include a regular follow-up of these 'new-miners.' If this scheme were efficiently carried out, then, in the course of 10–20 years, it would provide an index of present environmental conditions and the influence of concurrent preventive measures associated with increased mechanisation.

Knowledge of coalminers' pneumoconiosis after nearly 150 years of observation, study and research is still very imperfect, but even so enough is known for effective action to be taken.

## ACCIDENTS IN COALMINES

by

Sir Andrew Bryan

OF all the major industries in this country, coalmining is the most hazardous. Employing less than one-twentieth of the

working population, it accounts for nearly one-quarter of all industrial accidents. The reasons for this high incidence of accidents lie in the nature of the work of the miner and in the vital differences between his working environment and that of other industrial workers. Mining is for the most part a continual striving against great natural forces and hazards, both man-made and natural, in poorly illuminated and confined spaces within the crust of the earth.

A historical review of mining accidents showed that up to the present time, the attack upon the accident problem in coalmines has been mainly by way of statutory regulation and inspection, assisted by scientific research into specific mining dangers and a raising of the standards of education and training of mining personnel; and, more indirectly, by improvements in the standards of housing, welfare and recreational facilities for the mining community as a whole. That these lines of attack have achieved a considerable measure of success over the years is shown by the progressive reduction in the accident rates for fatal and serious non-fatal accidents. But there is still much to be done along these well established lines and this attack must undoubtedly continue by way of further regulations as the beneficial results of new mining methods, machines, safety devices and practices are proved; by way of higher standards of education and training for mine managers, officials and workmen; increased scientific research into specific mining dangers; by the general adoption of higher standards of engineering practice; and by the expansion of social and welfare activities in all mining communities.

But if the rate of progress in accident reduction is to be accelerated—as, (to put the matter on the lowest level) it must be, in view of the present serious manpower and production position—then it would seem that not only must the attacking forces along existing lines be reinforced, but new forces must also be brought to bear on a still broader front or, perhaps, on one or more new fronts. What new fronts can be suggested? Here are some suggestions for consideration and discussion.

In considering comparisons of the kind which follow, it has to be realised, that the hazards of coalmining are of many very different kinds and that they vary greatly and rather indeterminately as between coalfields, between mines in the same coalfield and even in different parts of the same mine, according to the geological and other natural conditions and to the extent and methods of working.

*Relationship between accident rate, absenteeism and size of pit*

A preliminary study of absenteeism and of the accident rate in one large mining area made it appear that these two features of behaviour were related to one another, and that each in turn was related to the size of the pits in which the men, absent or injured, were working. These possible relationships were then traced on a national scale with practically the same result. There was a significant positive correlation between the average size of the pits in a Division and the average absenteeism throughout that Division. The bigger the average size of pits, the higher was the absenteeism. There was a similar trend with the accident rate. For 949 individual pits that made returns in 1950 this was related to sizes of pits which were classified in eleven groups according to the numbers of persons employed, and the mean accident rate was computed for the pits in each group. This is shown in Table I.

TABLE I

| No. of Miners | No. of Pits | No. of Manshifts | Total Accidents | Rate per 100,000 Manshifts |
|---|---|---|---|---|
| 0–50 | 327 | 1,149,000 | 730 | 63·5 |
| 50–100 | 27 | 469,000 | 498 | 105·1 |
| 100–250 | 82 | 3,692,000 | 3,818 | 103·5 |
| 250–500 | 124 | 11,701,000 | 15,096 | 129·0 |
| 500–750 | 102 | 16,088,000 | 21,495 | 133·5 |
| 750–1,000 | 112 | 23,955,000 | 32,295 | 134·6 |
| 1,000–1,500 | 94 | 32,370,000 | 44,739 | 138·2 |
| 1,500–2,000 | 50 | 21,246,000 | 31,355 | 147·6 |
| 2,000–2,500 | 14 | 8,756,000 | 14,243 | 162·5 |
| 2,500–3,000 | 13 | 8,693,000 | 14,170 | 163·0 |
| 3,000 + | 4 | 3,528,000 | 5,882 | 166·6 |

A simple explanation for the higher rate in the bigger pits would lie in their more difficult geological conditions for, on average, the bigger pits are deeper and work

thicker seams. But against this there is the fact that no such trend is seen in the accident rate for ' falls of ground ' at the working face which one would expect to increase with the more difficult geological conditions—in other words in the larger pits on this argument. Statistics show that the accident rate from falls of roof or side at the working face almost doubles from the smallest pits to those employing between 500 and 750 men and that, thereafter, for pits from this size upwards, the rate remains practically constant. As the pits employing 500 men or more account for seven-eighths of the total manpower, it is a safe rule to say that, while the total accident rate increases steadily with the size of pit, the face accident rate from ' falls of ground ' remains nearly constant. It is likely, therefore, that factors other than ' conditions ' also enter into accident probabilities.

*Relationship between accident and incidence of pneumoconiosis in South Wales*

Although the South Western Division, which comprises the South Wales Coalfield, shows the same trend of accident rate with size of pit as the other eight National Coal Board Divisions, its overall accident rate is much above the national average. Why is this ? Difficult geological conditions may seem to provide the answer. But difficult though the geological conditions are, South Wales differs from the other Divisions in other ways. It has by far the highest recorded incidence of pneumoconiosis. It is relevant to ask whether this is likely to affect the general accident rate. This it might do in two ways : it might make the men less alert through physiological causes or it might have psychological effects. The fear of contracting the complaint may subconsciously increase the proneness of men to accident and injury. If an accident is, as Freud argues, partly an expression of a subconscious desire to get out of an unacceptable situation, it is natural to expect the accident rate to be higher in the pits with the larger incidence of the disease.

To test whether pneumoconiosis may be in part responsible for the higher accident rate, the returns for the South Western pits for a particular year were examined and the pits classified according to the incidence of the disease and the accident rate. Figures are available for all pits employing more than 100 persons below ground, giving the number of certified pneumoconiosis cases per 1,000 persons employed, between 1943 and 1949. It is reasonable to assume that at the pits with the higher incidence the men would now recognise there was a distinct probability of contracting the complaint; this might affect morale and might hence be reflected in the accident rate. Table II shows per 1,000 miners employed the position for all accidents in 1948 in the pits in the South Western Division.

TABLE II

| Incidence of Pneumoconiosis. Cases per 1,000 persons employed | No. of Pits | No. of Miners | No. of Accidents | Rate per 1,000 Miners employed |
|---|---|---|---|---|
| 0–100 | 77 | 43,577 | 9,188 | 211 |
| 100–200 | 48 | 32,494 | 7,966 | 245 |
| 200–300 | 28 | 19,204 | 5,609 | 292 |
| 300–400 | 17 | 10,929 | 3,288 | 300 |
| 400–500 | 6 | 4,857 | 1,250 | 257 |
| above 500 | 8 | 6,233 | 1,966 | 314 |
| | | | Average for Division | 247 |

With the exception of the smallest group of pits (with an incidence of pneumoconiosis between 400 and 500 cases per 1,000 persons employed) there is a steady rise in the average accident rate as the incidence of the disease rises. Where the incidence is very high the accident rate is almost half as great again as in the group of 77 pits that, judged by South Western standards, are relatively free of the complaint.

This analysis does not pretend to show whether the higher accident rate is due to psychological rather than physiological causes, or how far management enters into the question. Inferior ventilation might aggravate both pneumoconiosis and accidents. But the figures suggest that, if the division were entirely free of pneumoconiosis (or the factors that cause it), the accident rate would be lower, perhaps below 200 per 1,000 persons employed.

*Need for a detailed analysis*

It appears that, under existing conditions, the general proposition that men are more likely to suffer injury in the larger pits is adequately proved. But a more detailed analysis is called for in order to separate from the 'size-factor' the other influences, such as training and safety organisation, and the extent of personal supervision by the higher management, on the one hand, and physiological and psychological factors, such as lack of alertness or fear of industrial disease, on the other. Such an analysis would reveal far more than the accident patterns themselves. It calls for a study of all the facts of recorded accidents at the pits and places where they occurred as well as a ready reference to all available statistics, by a special team of trained investigators.

The value of research into observable features of human behaviour such as the accident rate and its relation to the size of the groups or communities in which men work, may, in the final result, lie in the light it sheds upon the structure of authority in the pit, and the extent to which the men feel themselves to be part of the organisation in which they are employed. Whatever the public may think about miners and whatever may be attempted in the way of reconstructing the industry, coal will always be got by small groups of men working in comparative isolation and under remote supervision. The need to understand the extent to which each man feels he is a member of the group, and the extent to which the groups identify themselves with the pit as a whole, is one of the most urgent investigations that confronts the industry to-day. The recorded facts alone can suggest how the need should be met.

# CONTINENTAL DRIFT

Postscript to the Report of a Discussion as published in *The Advancement of Science*, June 1951.

## The Psychology of Continental Drift

by

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The several papers on continental drift published recently in *The Advancement of Science* (1) make attractive reading. Even though most of the points developed in these papers have a familiar aspect, and no strikingly new ideas or facts are presented, the symposium has value as an up-to-date report on the status of a problem that holds perennial interest. Moreover the critical reader of such papers derives considerable diversion, and perhaps some profit, from attempts at analysing the several authors.

My attention has been attracted particularly to the paper by H. E. Hinton (2), who aims one of his darts at a humble contribution (3) in which I essayed a brief analysis of some arguments urged by Wegener and du Toit as 'compelling.' Hinton (*op cit.*, p. 77) lists me among the deliberate opponents of continental displacement, and pronounces a portion of my paper 'absurd.' 'To see oursels as ithers see us' is a worthy objective, and Hinton's verdict has led me to a critical review of the offending passage, which is concerned with the high rank that is assigned, by leading proponents of 'drift,' to the fossil *Glossopteris* flora as evidence for a former union of southern continents. I question this emphatic evaluation by citing the known distribution of primitive living dogwoods such as *Cornus* (present in eastern North America, in south-eastern Asia, in New Zealand and other south Pacific islands, absent from Australia, from South America, and from islands of the north Pacific); and I outline Brown's (4) reasonable theory to account for this remarkable distribution without invoking once-continuous land connections, for which indeed no plausible argument can be advanced. Any suggestion of human agency is ruled out; relationships among the several genera convinced Brown that the ancestral forms probably migrated into the Pacific as early as Cretaceous time (4, p.21).

Hinton's failure to see the pertinence of *Cornus* suggest some amplification of the argument. Presumably the dogwood is no more seaworthy than were species of *Glossopteris*. If we consider the present geographic situation for both groups, critical oceanic distances of separation are far greater for *Cornus* than for *Glossopteris*, and climatic barriers between the south Pacific islands and the northern continents are more formidable than any within the southern hemisphere. If rafting on ocean currents is invoked as an important means of distribution, surely *Glossopteris* enjoyed a large advantage, since continental masses are much more effective than scattered islands in intercepting rafts. Therefore the confident assertion, by Wegener, du Toit, and others, that lands bearing the *Glossopteris* flora necessarily had direct connection is not justified. This is the whole import of the passage in my earlier paper which Hinton interprets as a frontal attack on the displacement hypothesis. But of course continents may have drifted regardless of the method by which *Glossopteris* was distributed. Incidentally, I have wondered what ardent proponents of 'drift' would say if the widely separate areas occupied by *Cornus* were so situated as to fit nicely into their picture of continental displacement.

My contacts with the displacement concept have included fairly close acquaintance with a number of the leading protagonists, field study of several critical geologic features (including impressive exhibits fashioned by late Paleozoic glaciation), and reading of considerable pertinent literature. The concept raises exciting possibilities, and the stimulus it has given to scientific thinking and research

has beyond doubt been constructive. It remains in my list of live hypotheses, though I continue to wonder at the strange zeal it has inspired in some of its avowed disciples. Wegener, a master at lucid expression, was notably uncritical in matters related to ' drift ' ; to him the lower latitude in North America than in Europe of the Pleistocene terminal moraine was testimony to displacement as eloquent as the distribution of older glaciated areas in the southern hemisphere. Du Toit, whom I knew with liking and respect, could not endure the flimsy argument based on the terminal moraine, but offered suggestions fully as ludicrous, such as the idea that a continental mass moving equatorward is subjected by diverging meridians to disrupting tension, whereas movement toward the pole results in compression because of converging meridians (5). Glaring contradictions appear in his statements regarding the biological evidence bearing on ' drift ' ; generally he assigned high value to this evidence, but at intervals he expressed the view that ' geological evidence almost entirely must decide the probability of this hypothesis, for those arguments based upon zoo-distribution are incompetent to do so ' (6). More than once I have suspected that both Wegener and du Toit became convinced of their primary duty to preach the gospel of continental drift as widely and forcefully as possible, without primary consideration to scientific accuracy and consistency. Their fervour had a religious quality.

Avowed partisans of the ' drift ' concept habitually present their arguments in terms which to a majority of scientific workers smack of exaggeration or over-emphasis. Thus Wegener claimed six major geological ' controls ' that bolster his concept of an Atlantic basin opened by continental displacement. Although these ' controls ' are questionable in varying degree, and at least one—the Pleistocene moraine—has no conceivable worth, Wegener assumed for the six equal exponential value, and set up his own equation to represent the odds on ' drift ' as a million to one. Du Toit repeatedly described as ' compelling ' evidence that seems at best no more than suggestive, and announced that certain botanical and zoological data ' prove the continuity of the various parts of Gondwana from the Permian to the Rhaetic ' (7). Hinton, in an appraisal of figures published by G. G. Simpson, decides ' that they constitute one of the best zoogeographical proofs (*sic*) of the displacement theory.' Another group habit of these partisans is to assume that any critic of their arguments is automatically a member of an opposing camp who undertakes the criticism with the sole motive of disparaging the displacement concept. This attitude, conspicuous in du Toit's writings, appears also in Hinton, who by implication classifies earth scientists as ' drifters ' and ' anti-drifters ' (*op. cit.*, pp. 76–77). My citing of facts on floral distributions could not conceivably reflect an objective viewpoint—it was an attempt to marshall ' evidence against continental displacement.'

Thus this theory confronts us with psychological as well as physical problems. I have sometimes wondered whether the concept induces in its close adherents a mental transformation, or whether it merely attracts to its inner fold those who fall into a certain mental pattern. Du Toit, it seems, came to regard himself as a lonely voice crying in an unappreciative wilderness of ' orthodoxy.' Perhaps a feeling of isolation, in a restricted group devoted to a doctrine that many regard as radical, creates a defensive attitude and results in behaviour somewhat strange to the scientific fraternity. Surely the hypothesis of ' drift ' is now out of its swaddling clothes, and must make its way on its merits. Adherents will have to realise that arguments for a theory with implications so drastic will continue to face analysis not merely exacting but merciless. The analysts, by and large, are not inveterate ' anti-drifters ' ; many have a genuinely friendly interest in the displacement concept, but they insist that it be rigidly tested, like any other hypothesis, in truly scientific fashion.


REFERENCES

(1) ' The Theory of Continental Drift.' Six papers of a symposium, Sept 1, 1950. *Adv. of Sci.*, 1951, vol. VIII, **29**, 67–88.

(2) HINTON, H. E. (1951). ' The Wegener-Du Toit Theory of Continental Displacement and the Distribution of Animals.' *Adv. of Sci.*, vol. VIII, **29**, 74–79.

(3) Longwell, C. R. (1944). 'Some Thoughts on the Evidence for Continental Drift.' *Amer. J. Sci.*, **242**, 218–231.
(4) Brown, F. B. H. (1928). 'Cornaceae and Allies in the Marquesas and Neighboring Islands.' *Bernice P. Bishop Mus. Bull.* **52**, Honolulu, T. H.
(5) Du Toit, A. L. (1937). *Our Wandering Continents*, p. 305. Olwer & Boyd, Edinburgh.
(6) Du Toit, A. L. (1944). 'Tertiary Mammals and Continental Drift.' *Am. Jour. Sci.*, **243**, 146.
(7) Du Toit, A. L. *Our Wandering Continents*, p. 86.

## On Longwell's 'The Psychology of Continental Drift'

by

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Some plant and animal groups are more easily distributed than others. A number have in one way or another managed to survive transport for immense distances across the ocean. For instance, some have colonised Pacific islands of Late Tertiary origin. The occurrence of plants and animals on volcanic islands always far removed from any continent is absolute proof, or so it seems to me, that these can survive long-distance transportation. The physiological and other requirements of many groups of animals and plants are now sufficiently known so that we can assess with some confidence the possibility of their survival under conditions to which they would be exposed in any long distance sea-borne or air-borne journey.

The claim that because group A can survive transportation across the ocean it is likely that group B can do so also will carry little conviction unless there be evidence of some similarity in the requirements of the two groups. *Cornus* is not related to *Glossopteris* nor is any evidence available of a similarity in the environmental requirements of the two. It is the method of all sophists of all times to cite examples relating to basically dissimilar cases. I quoted Longwell's paper only because I wished to quote a particularly obvious example of a certain method of argument. Longwell has done me the favour of drawing attention once more to his method of argument.

Instead of continuing to expend their energies on *Glossopteris*, the opponents of the Wegener-Du Toit theory might now more profitably employ their time in finding some explanation other than ours for the distribution of the Permo-Carboniferous coal and glacial deposits.

Longwell suggests, without actually saying so, that my analysis of Simpson's figures for Triassic reptiles is incorrect. The conclusions I drew from those figures are the exact opposite of those drawn by Simpson. We cannot both be right. The reader will doubtless judge for himself which one of us is wrong.

By his choice of the title, 'The Psychology of Continental Drift,' Longwell may mean us to know that his article is not intended to be a contribution to the theory of continental drift. As an essay in psychology it adds as little to that field as to the other.

# PHYSICS OF SOCIAL EQUILIBRIUM[1]

by

DR. R. FÜRTH

IN this lecture an attempt is made by a physicist, who has little knowledge of the social sciences, to come to a clearer understanding of some social phenomena on the basis of his experience in the domains of experimental and theoretical physics. The results of my considerations seem to me to be interesting enough to justify their presentation to a wider public, and I am quite willing to take the blame for not following the rule 'Every jack to his trade,' since I believe that progress towards the important aim of a unification of science can only be achieved by violating this and similar tenets.

The use of simplified models for the theoretical understanding of physical phenomena, and for the purpose of their application to practical problems has been generally recognised for a long time. A whole history of physics could in fact be written on the leading principle of certain models like 'ultimate particles,' 'ether,' 'waves,' etc., and strictly speaking, theoretical physics deals with nothing else but models of real things. Physical models can, of course, also be used for representing the mechanism of non-physical phenomena, for example biological processes. A very well known example is the representation of a living organism by a heat engine and the application of the laws of thermodynamics to its functioning.

Physical models for the understanding of certain social phenomena have also frequently been used, mainly by economists, and political writers. The knowledge of physics of these men is, as a rule, confined to what they have learned at school and can scarcely be expected to be up-to-date. Also, owing to their lack of training in the natural sciences they tend to oversimplify things and to be led by superficial analogies. As a result the conclusions reached from such considerations are often wrong and, if put into operation, might lead to disastrous results, just as the use of not properly founded principles in engineering can result in industrial accidents.

Models of the kind mentioned are usually based on classical mechanics, like the statics of solid structures, the movement of rigid bodies under the influence of forces, and the working of mechanical machines. The three following examples will serve to demonstrate the fallacy of this kind of argument.

The model of a solid structure (like a framework) for a social community led to the concept of 'forces,' acting on the whole or part of this community, which can 'balance' each other so that 'equilibrium' can be established. The use of this model rests entirely on the supposed analogy between 'forces' in the strict sense of physics and in the loose sense of everyday language. Now, in physics force is a well-defined and measurable quantity which has the mathematical characteristics of a vector as can be proved by experiment. Hence, by superposition, a number of forces acting on one and the same object, e.g. part of a solid structure, can cancel out, and this is the condition for 'equilibrium.' But what the sociologist or politician means by 'force' is just 'strong influence'; it can neither be defined mathematically nor measured quantitatively, and there is therefore no justification for the assumption that a superposition of various such 'forces' can ever lead to their mutual compensation. Besides, there is no reason to assume that this would result in the establishment of an equilibrium, that is a stationary state where no changes take place in the course of time.

The model of a rigid body, held in

[1] Slightly altered text of a lecture delivered to the Physics Section at Edinburgh, August 15, 1951.

stable equilibrium by external forces and performing periodic oscillations about the equilibrium position when that equilibrium is disturbed by a transient disturbance, is also often used for predicting what is going to happen if the state of a social community is disturbed by some unexpected event. The ' swing of the pendulum ' is a favourite catch-phrase of popular writers, and the general public is led to believe that a certain trend of development, resulting from such an event, is bound to come to a stop sooner or later and eventually to revert to the starting point. But this conclusion is absolutely unwarranted. Although it does follow from the definition of stable equilibrium that a rigid body will perform small oscillations about the equilibrium position when the equilibrium has been slightly disturbed, it is impossible to predict whether a given system of rigid bodies will behave in this way unless it is already established (by the mathematical analysis of the expression for the energy function) whether the system in fact satisfies the stability criteria. Thus unless an analysis of a similar kind is possible in the case of a social community and is actually carried out, a statement of the sort mentioned is quite irrational and only apt to induce the man in the street into believing that present difficulties will in due course resolve themselves automatically by the working of some miraculous social mechanism.

As a third example I want to mention the often alleged analogy between a social community and a mechanical machine. The latter is a construction in which every part is directly or indirectly linked up with every other part so that the movement of the machine can proceed only in the way intended by the designer. It will consequently break down whenever any of its parts is damaged or worn out. The popular belief in the analogy between a social structure and a machine is revealed in such phrases as ' machinery for control ' or ' machinery for settling disputes,' etc. The consequent development of this idea must lead to the concept of a human society, completely planned by some designer outside that society and much superior in intellect to the members of the society, and kept under constant strict supervision so that every fault can immediately be remedied and any worn-out part removed and replaced. The fallacy of this whole analogy is obvious. For the designers and controllers of a social community belong in fact to that community, so that the community would be the analogue of a machine that designs, controls and repairs itself ; but this is a contradiction to the whole concept of a mechanical machine. The essence of the proper working of human society is in fact voluntary and intelligent mutual co-operation between its parts.

All mechanical models for social processes are, of course, based on the idea that these processes are governed by causal laws of the same nature as those which, according to classical physics, rule in the realm of mechanics. Also, from this point of view, social structures are regarded as units as are structures of solid bodies, irrespective of the fact that the former consist of a multitude of individuals and the latter of a large number of constituent particles. However, for a great variety of social phenomena, in particular those which are amenable to quantitative measurement, data about the behaviour of a community as a whole are obtained by collecting the corresponding data for a large number of individuals, that is, by making statistical surveys. Surprisingly enough these statistical data have to some extent the regular features of causal laws and thus allow predictions of some accuracy to be made, although the individual events which make up the statistical material are almost unpredictable. I refer to such phenomena as the number of births and deaths, marriages, illnesses etc., occurring in a community within a certain period.

The analogy with certain ' games of chance ' like the throwing of dice and roulette, or more generally with statistics of large numbers of repeated trial experiments on one and the same object, or independent trials on a large number of identical not interacting objects, suggests itself very strongly. ' Statistical laws ' for such phenomena can be derived by means of the probability calculus under the following assumptions : Firstly, that fixed ' probabilities,' expressed in the form of numerical fractions, exist for the

various possible results of individual trials, secondly that the relative numbers of these results within a large collection of trial data are equal to the respective probabilities. These assumptions are justified *a posteriori* in the mentioned cases by the success of the theory, and this not only makes it possible to predict expected numbers of certain events but also probable deviations from these expected values.

Sociologists have in the past been only too eager to apply statistics to social phenomena of the type mentioned, and to assume that they are governed by the rules of the roulette table. Again it must be emphasised that this statistical model is inadequate and that predictions based on the statistics of chance games can be completely wrong. For there is no justification for assuming that the fate of the individual is subject to fixed probabilities, nor that it is independent of the behaviour of other individuals within the same community at the same time or some previous time. Finally it does not seem possible to make a rational estimate of the errors to which these statistical predictions are liable.

A few examples will make this clearer. Statistics of propagation and death rates over a number of years in a certain country may show that its population increases annually by a certain percentage. Accordingly the prediction is made that the population will have increased by say 20 per cent. in 1980. But this statement rests entirely on the assumption that fixed probabilities for birth and deaths exist which do not change in the course of time, and such an assumption is certainly unjustified as external and internal events and developments must undoubtedly have a profound influence on the propagation and death of individuals.

Another example is a prediction on the increase of the population of a country based upon statistics of immigration over a number of years. These may show a fairly steady trend, and thus a prediction on statistical grounds may seem reasonable. However, actual events in the future may turn out to be very different from the predictions because the decisions of potential immigrants are obviously influenced by personal contact with people who have already immigrated and these influences can be either encouraging or deterrent. Such complications do not occur in chance games like roulette where, contrary to popular belief, the fate of the spinning ball is in no way influenced by the results of previous games.

As a third example I want to mention the predictions on certain topical events, like the outcome of elections, by public polls. The results of such polls are always published in the form of percentages of a number of interviewed people favouring one or the other event, but the absolute numbers are very rarely stated. It is quite impossible, on the basis of the relative numbers alone, to say whether a certain increase or decrease of the published figures from one poll to the next has any significance at all, because it may be just a chance fluctuation. In actual fact, even if the absolute numbers are known, an estimate of the probable accuracy of a prediction is hardly possible as the statistical methods for such estimations rest on the assumption that each voter casts his vote for one or the other party according to a fixed probability and that he is not influenced in his decision by the intentions of other voters, for instance by the publication of previous polls; this assumption is certainly not justifiable.

It is rather surprising that both kinds of models, the mechanical and the statistical, have been used separately for representing social phenomena, but that apparently no attempt has been made by sociologists to unify the situation by adopting a model incorporating both the causal and the chance aspect. In physics this unification has been brought about during the last half-century by the development of 'statistical mechanics,' a branch of physics which has now become an indispensable tool for the theoretical treatment of many physical phenomena. Its principal field of application is the physics of systems consisting of a very large number of particles of the same kind, so-called 'assemblies' of particles. But it can also be supplied to assemblies of other physical entities such as electric circuits or waves.

Now, social communities are also assemblies consisting of individuals who in

many ways show similar behaviour. It may therefore be expected that the assemblies of statistical mechanics could be used as adequate models of social communities, and the experience gained in the study of the physical behaviour of molecular assemblies by the methods of statistical mechanics could be usefully employed in the guiding and shaping of human society.

In the early stages of its development the application of statistical mechanics was restricted to assemblies of particles with weak mutual interaction, like gases. But more recently considerable progress has been made in the application of statistical mechanics to close assemblies, like liquids and solids, where the particles interact strongly with each other. For loose assemblies under the action of external forces it is possible to calculate from general theorems of statistical mechanics fixed probabilities for a particle to be found in a certain position and orientation, irrespective of the position and orientation of the rest of the assembly. But in close assemblies these probabilities depend on the configuration and orientation of all the other particles, in the first place of course those in the immediate neighbourhood of the considered particle. This ' co-operation ' between the particles may either enhance or reduce the probabilities for certain configurations. Phenomena, mainly in solid and liquid matter. which are the outcome of such processes are called ' co-operative phenomena.' The following examples may serve as illustrations.

The first example is taken from the theory of ferro-magnetism. Single crystals of a ferromagnetic material, like iron or nickel, are always found to be magnetised to saturation at normal temperatures, even in the absence of external magnetic fields, although the probabilities *a priori* for the magnetic axis of any of the constituent atoms to point in the direction of any of the crystallographic axes are equal. Hence complete disorientation of the magnetic axes should result according to the previously mentioned fundamental statistical theorems. The explanation is, that in these substances the mutual interaction between neighbouring atoms is of such a kind that it greatly favours parallel orientation of the magnetic axes. Hence once, by some chance event, parallelism of the axes is established in a very small volume of space the co-operative interaction will increase the probabilities for the orientation of adjacent atoms in the same direction, and thus the process of adjustment of orientation will rapidly spread through the crystal until it is uniformly magnetised throughout.

A second example is provided by the theory of phase transition in solids. At the absolute zero point of temperature each possible configuration of the atoms in a piece of matter will have a certain probability depending on the mutual potential energy of the particles. The most stable configuration, which will establish itself, is the one with the greatest probability and this configuration will, as a rule, be a regular array of the particles in a so-called crystal lattice of a certain type. At finite temperatures the particles perform irregular oscillations about their equilibrium positions, and these cause a change of potential energy and consequently of the configuration probabilities. Thus it may happen that at a certain temperature the probabilities of two different configurations in two different types of crystal lattices become equal. The slightest rise in temperature will then produce a sudden switch-over from one structure to the other. Many cases of this type of phase transition are known.

As a third example we discuss briefly the question of the strength of solids like metals. It is a well known fact that a piece of very pure metal, say copper, in the form of a single crystal has extraordinarily little strength and can easily be deformed or broken, whereas the same copper in the usual form of a mosaic of little grains of crystals with irregular orientation is very much stronger and tougher. One can further strengthen the material by mixing it with some other metal to form an alloy, for example by mixing copper and tin to form bronze. And the strength of bronze can again be greatly increased by the addition of small quantities of phosphorus. The explanation is roughly speaking that the process of plastic deformation of solids is a typical co-operative phenomenon. The more uniform the structure the stronger will be

the co-operative interaction which tends to spread any fault of the structure, arising at some point from the action of external forces, through the whole body, similar to the formation of a ladder in a stocking. But if the co-operative tendency between neighbouring particles is reduced, either by the creation of interfaces between the grains or by the interposition of foreign atoms, these processes are stopped almost at once and consequently the structure is strengthened and not weakened as one might have expected from a superficial consideration.

Similarly co-operative phenomena may be expected to occur in close assemblies of entities other than material particles, e.g. systems of great numbers of interrelated electric circuits, like telephone exchanges or electronic computators etc. In the realm of biology all organisms are assemblies of cells, and in particular the brain provides an example of a close assembly of this kind where the cells interact very strongly, mainly by transmitting electrical impulses to each other. It is indeed generally accepted by physiologists that co-operative phenomena play a very important part in the functioning of the brain.

Communities of animals and human beings are clearly also assemblies in which the interaction between the individual members is very considerable. It would therefore be quite wrong, as was already pointed out, to use a loose assembly of particles as a model for a social community. On the other hand the interaction is by no means as rigid as in a mechanical machine which was the reason for rejecting models of this sort. Thus we are almost forced to adopt the model of a 'close assembly,' and by doing so we must expect to find the features of the co-operative phenomena of statistical mechanics in many social processes. For the fundamental assumption made is only that there exists a strong 'interaction' of some sort between the members of the community; whether this interaction is of a physical or a non-physical, conscious or unconscious, nature is unessential. This may be illustrated by the three previously mentioned examples of co-operative phenomena in physics.

In the last decades we have experienced a growing trend towards the formation of what we may call 'pure communities' of people belonging to the same race, whatever that means, speaking the same language etc., and towards self-government and complete sovereignty of such communities. The interaction between the members of such a community naturally induces neighbours and friends to imitate the external habits and ways of thinking of each other. Thus we may expect to see the analogue of ferromagnetic magnetisation to operate, that is to say, a complete uniformisation in one or other direction to develop rapidly, once a small nucleus has been formed within the community. I believe that this is the clue for the understanding of the rapid spread of fascism or communism, and the obvious lesson to be drawn from it is that the formation of 'pure' communities is definitely dangerous for the maintenance of democracy.

The question of social stability appears now in a new light. Instead of being comparable to the equilibrium of a rigid mechanical structure or an oscillator, like a pendulum under the action of external forces, it is now seen to be the analogue to the equilibrium of a close assembly of particles like a piece of crystal, under the opposing influences of the interatomic forces and the thermal agitation of the constituent particles. The counterpart of the thermal movement in human societies is the seemingly erratic behaviour of the individual which gives rise to a certain amount of 'unrest,' comparable to the temperature of a material body. Normally an increase in 'temperature' will result in a gradual and continuous change in the structure of the community, but under certain conditions we may expect a sudden and discontinuous change from one structure into another to occur in a 'revolutionary' development. This is not necessarily a bad thing, and one has also to keep in mind that such structural changes can be at least partly reversible, just as in the formerly discussed phase transitions in crystal physics. Examples of such processes are the rapid adjustment of habits and outlook in a community in an acute emergency, and the relapse into more or less the former state of affairs when the emergency has passed.

Finally let us consider what we may call the ' strength ' of a social community, the analogue to the strength of a material body. Just as a material body is subject to irreversible plastic deformations, and eventually to rupture under external stress, a social community will inevitably suffer irreversible changes in shape and may even be broken up altogether by external influences. The former process, if kept within reasonable limits, is a normal and indeed necessary development as it serves to adjust the community to changing surroundings. The latter process is definitely undesirable, and sociologists and politicians should try to understand the mechanics of rupture and learn how it can be avoided.

I have already pointed out how easy it is to re-orientate a ' pure ' community, and from what we know about the strength of single crystals of pure substances we may predict that the shape of such a pure community will also be changed very easily and perhaps even broken up by external activities. In order to establish a ' stable ' human society it is therefore necessary to encourage the function of opposing activities within a community in the form of free discussion and by education to independent thinking, and also to allow a certain amount of mixing of population to take place. The breaking up of states with mixed population into small sovereign ' national ' states, the separation of races within a community, the expulsion of minorities of different race and language, and the erection of barriers to prevent the ' infiltration ' of a population by ' aliens,' all these measures have been put into practice for strengthening social communities, and we have had ample experience in the past to see that they produce exactly the opposite effect. On the other hand the remarkable stability of democratic communities with mixed population, such as Switzerland, the United States and the British Commonwealth of Nations may at least partly be ascribed to the soundness of their structures on the principles of strength of material bodies. Let us hope that future statesmen will turn from party doctrines to scientific principles if they wish to establish a stable equilibrium in human society.

# SEISMOLOGICAL INVESTIGATIONS

FIFTY-SIXTH REPORT of COMMITTEE on Seismological Investigations. (Dr. R. STONELEY, F.R.S., *Chairman*; Lt.-Col. E. TILLOTSON, *Secretary*; Mr. E. F. BAXTER, Miss E. F. BELLAMY, Prof. P. G. H. BOSWELL, O.B.E., F.R.S., Mr. B. C. BROWNE, Dr. E. C. BULLARD, F.R.S., Dr. K. F. CHACKETT, Dr. G. E. R. DEACON, F.R.S., Dr. A. T. J. DOLLAR, Rev. H. NORMAN EDGE, Dr. A. E. M. GEDDES, O.B.E., Prof. G. R. GOLDSBROUGH, C.B.E., F.R.S., Dr. M. N. HILL, Dr. O. J. R. HOWARTH, O.B.E., Mr. J. S. HUGHES, Prof. H. JEFFREYS, F.R.S., Mr. E. N. LAWRENCE, Dr. A. W. LEE, Dr. A. O. RANKINE, O.B.E., F.R.S., Rev. C. REY, S.J., Dr. G. D. ROBINSON, Mr. H. V. SHAW, Sir FRANK SMITH, G.C.B., G.B.E., F.R.S., and Dr. P. L. WILLMORE.)

MEETING OF COMMITTEE.—The Committee met on Thursday, August 31, 1950, in the Physics Department Library, The University, Edgbaston, Birmingham, and also on Friday, July 6, 1951, in the rooms of the Royal Society, Burlington House, London, W.1.

## THE GRAY-MILNE FUND

During the year ended June 30, 1951, no disbursements have been made from this Fund beyond insurance, secretarial expenses and the cost of duplicating and circulating the data that have been compiled by Lt.-Col. E. Tillotson from the Edinburgh Records. The trust income remains as in previous years, and £10 has accrued as interest on Defence Bonds.

*Gray-Milne Fund*

| *Receipts* | £ | *s.* | *d.* |
|---|---|---|---|
| Balance at Bank, July 1, 1950 | 198 | 10 | 0 |
| Trust Income . . . | 80 | 14 | 10 |
| Interest on Defence Bonds . | 10 | 0 | 0 |
| | £289 | 4 | 10 |

| *Payments* | £ | *s.* | *d.* |
|---|---|---|---|
| Insurance on Seismographs . | 1 | 0 | 0 |
| Secretarial Expenses . . | 8 | 11 | 6 |
| Balance in Bank, June 30, 1951 . . . . | 279 | 13 | 4 |
| | £289 | 4 | 10 |

In addition, the sum of £400 remains temporarily invested in Defence Bonds.

## INSTRUMENTS

The instruments belonging to the Committee are located as follows :—

| | |
|---|---|
| Milne-Shaw Seismographs, | |
| No. 1 . . . | Downe, Kent. |
| „ 3 . . . | Edinburgh. |
| „ 4 . . . | Downe, Kent. |
| „ 6 . . . | Hermanus, South Africa. |
| „ 27 . . . | Perth, Western Australia. |
| „ 63 . . . | Suva, Fiji. |
| Seconds Regulator Clock . . . | Suva, Fiji. |
| Jaggar Shock Recorder | Fort Augustus. |

The Seismographs at Down House, Downe, Kent, remain in storage.

Dr. A. T. J. Dollar has published his review of Scottish Earthquakes 1916–1949 in the Proceedings of the Geological Society of Glasgow (*Proc. Geol. Soc. Glasgow*, Vol. XXI. Part II, pp. 283–361), and is working on a similar review of English and Welsh Earthquakes.

## INTERNATIONAL SEISMOLOGICAL SUMMARY

*By J. S. Hughes and R. Stoneley*

The publication of the International Seismological Summary for 1939 is completed and all four quarterly numbers have been issued. Work is proceeding with 1940 and the first six months are now in the hands of the printers; a third quarter is nearly ready for a final check and will be sent to press in due course. During the calendar year 1950 six quarterly numbers were distributed, but until an

increase of staff is obtained it is doubtful if this rate could be maintained. So far this year only two numbers—1939 July–Sept. and October–December have been put out though all proofs for the first part of 1940 have been passed and its production should soon be effected.

Work on the preparation of data for 1941 proceeds but there does not appear to be any very great reduction in quantity though of course there is some falling off in the number of stations. It seems better for the work to go forward continuously, as the shortage of data during the war years may lead to some speeding up of the rate of production and it is questionable whether these war years would ever be dealt with if they were passed over now.

The finance of the I.S.S. has been a matter of anxiety right from its earliest days, and despite all attempts at economy in production the expense has rapidly risen in recent years on account of the general rise in the cost of staff and printing. After the Second World War it was clear that resources of the International Association of Seismology were inadequate to carry on the project, to which indeed the B.A. could by then offer only a relatively small subvention. In face of this difficulty the I.A.S. appealed through the U.G.G.I. to U.N.E.S.C.O. for substantial help towards maintaining the I.S.S. This help was generously given by U.N.E.S.C.O. and indeed without this assistance it seems clear that the I.S.S. would have come to a standstill. Even so, in face of its other heavy responsibilities U.N.E.S.C.O. has had to decrease the annual grant, and is unable to guarantee annual grants for a term of years. In 1950 the work would have had to cease but for a special grant of £1,000 made by the U.G.G.I.

The uncertainty concerning the long-term finance of the I.S.S. has made it impossible to engage extra staff in an attempt to make up some of the arrears of publication. Largely through the War, the I.S.S. is about 11 years in arrears, and the reduction of this to about 3 years, the minimum time needed for collection of data and computation of epicentres, is strongly urged by seismologists. The most that the present staff could do would be to bring out one extra quarterly number a year, which would imply a wait of some 30 years before arrears could be overtaken. On the representations of Prof. Jeffreys the British National Committee considered this question and agreed to ask the Royal Society to make a special appeal to the Treasury for a substantial grant towards reducing the arears of publication in a reasonable time and to this the Treasury has acceded. It is a fitting tribute to the pioneer work of Milne and Turner that the action of the British Treasury will enable this vital scientific project to continue to have its home in the country of its origin.

To speed up the rate of production of the I.S.S., however, means that the existing accommodation at Kew would be inadequate. To meet this difficulty the Director of the Meteorological Office has generously allowed the I.S.S. the use of the North Clock Room and the South Octagon Room in the main building of Kew Observatory, so long as these rooms are not needed for other purposes. Seismologists will be grateful to the Director of the Meteorological Office and to the Director of Kew Observatory for the great help and facilities that have been afforded to the I.S.S.

### Department of Geodesy and Geophysics, Cambridge.

Seismic Refraction Experiments in the North Atlantic.—Messrs. T. F. Gaskell and J. C. Swallow have applied the method of Hill and Swallow (see last year's Report) during a survey cruise of H.M.S. *Challenger* during the summer of 1950. Five stations in the North Atlantic were occupied and lines up to 17 miles long were shot, giving 10 to 15 first-arrival observations.

(1) 47° 40′ N., 13° 40′ W. (2,540 fathoms). Underneath a layer of perhaps partially consolidated sediment a single layer was observed, with P wave velocity 19,100 ft./sec. (5·7 km./sec.), which might consist of granite or palaeozoic sedimentary rock. If the velocity in the overlying material is taken as 6,000 to 8,000 ft./sec. its thickness would be 2,500 to 3,500 ft., which is significantly different from the 9,200 ft. found by Hill and Swallow some 400 miles to the N.W.

(2) 41° 46′ N., 35° 30′ W. (2,270

fathoms) on the W. of the Atlantic Ridge. A single layer with velocity 22,000 ft./sec. (6·6 km./sec.), with an upper layer about 800 to 1,200 ft. thick according to the previous assumption.

(3) 36° 08′ N., 62° 16′ W. (2,750 fathoms). Two layers, with velocities 14,300 and 23,400 ft./sec. (4·3 and 7·0 km./sec.). The first layer extends from near the sea bed to 12,000 ft.

(4) 32° 04′ N., 69° 39′ W. (2,920 fathoms). Three layers, with velocities 6,800, 15,200, 20,800 ft./sec. (1·8, 4·6, 6·8 km./sec.). The two upper layers are respectively 1,500 and 5,500 ft. thick.

(5) 27° 48′ N., 68° 28′ W. (2,880 fathoms). Three layers, with velocities 6,800, 18,400, and 23,600 ft./sec. (2·1, 5·5, 7·1 km./sec.). The thicknesses of the upper layers are 2,400 and 5,400 ft. respectively.

Except perhaps at Station (1) there is no indication of any thick granitic layer. The experiments did not determine the thickness of the high-velocity layer.

A fuller report of this work appeared in *Nature*, vol. 167, p. 723, May 5, 1951.

SEISMOGRAPHS.—Dr. Willmore's seismograph, described in last year's Report, is in process of development by Messrs. Hilger & Watts, and a working prototype has been completed.

During the recent outbreak of tremors in St. Kitts and Nevis, Dr. Willmore at the invitation of the Colonial Office spent three months in the earlier part of 1951 on a preliminary general seismic and vulcanological survey of the West Indies. A fuller report will be published in due course.

THEORETICAL.—In earthquakes recorded at moderate distances it has been noticed that the S Phase appears first as SH, followed some 10 to 14 sec. later by SV; it has been suggested by Prof. Byerly that this phenomenon may arrive from double refraction. The type and extent of the anisotropy to be assumed for the Earth's crust is of course entirely conjectural, but Dr. Stoneley has shown that for a 'transversely isotropic' crust with the anisotropy as strongly marked as in beryl a surface layer some 30 km. thick would account for a time difference between SH and SV of only about 1½ sec. Thus, this explanation does not seem very probable, although a different choice of elastic constants might allow of a much greater time difference. Meantime, Miss Lehmann's explanation in terms of the small angle that the S-oscillations make with the horizontal seems the more likely.

It is appropriate to mention here that Miss M. Newlands, of the Faculty of Mathematics, has recently completed a long and intricate investigation of the disturbance set up by a line source, of compressional or of distortional type, in a uniform surface layer resting on a 'semi-infinite' medium. This work, which is a generalisation of the researches of Lamb, Nakano and Lapwood, for a uniform medium, should throw considerable light on the interpretation of records of near earthquakes and of explosions. The number of onsets is large, and as is to be expected from the investigations of Nakano and Lapwood, not all the onsets correspond to stationary-time paths. The theory of the surface-wave phase is much more complicated than for a homogeneous medium.

*University of Leeds, Department of Mining.*—Research is being continued into the nature of seismogram structure at distances up to one mile from explosions. Pulses of a Rayleigh type have been observed, confirming the findings of Leet and others, which in certain cases constitute the maximum record amplitude.

The investigations of Ricker's theory suggest that this is insufficient to explain the general character of the seismograms obtained, although it may constitute a contributory mechanism.

## THE GREAT SIKANG-ASSAM EARTHQUAKE OF AUGUST 15, 1950

*By Ernest Tillotson*

At about 7.45 P.M., local time, on August 15, 1950, there occurred on the borders of Sikang and Assam one of the two greatest earthquakes ever recorded instrumentally. The other earthquake occurred on January 31, 1906, in Colombia. Both shocks attained magnitude 8·6 on the Richter logarithmic scale. According to S. L. Malurkar of Colaba Observatory, Bombay, the epicentre, as calculated

at Poona from Indian observations was latitude 29° N., longitude 97° E., whilst the epicentre calculated from data from 86 observatories at greater epicentral distances throughout the world, by Dr. E. Peterschmitt and Prof. J. P. Rothé was latitude 28°·6 N., longitude 96°·5 E. There is no suggestion that the depth of focus was other than normal, and with the latter epicentre the initial time was 14h. 09m. 30s. G.M.T. At the Colaba Observatory the initial displacement of the E.W. component Milne-Shaw Seismograph threw the counterpoise weight on the mirror arm and prevented further recording. On the N.S. component both P and S can be detected, but the general amplitudes are very great. Even in the small magnification Omori-Ewing instruments the Long Wave Phase movements caused the pens to bang against the sides of the instruments. The earthquake was well recorded in Great Britain though for example at Aberdeen the amplitude of the M Phase exceeded 3,170 $\mu$.

The epicentral region, near the Lohit River is sparsely populated and Capt. F. Kingdon-Ward who was camping there with his wife has sent a very vivid description of the occurrence to *Nature*. Damage was widespread in Assam and the earthquake was felt over a wide area extending almost to Banaras in the west, and to Rangoon in the south. Aftershocks were numerous, and up to September 30, 1950, some 45 aftershocks were recorded by the Colaba seismographs. The aftershock on September 13, 1950, at 16h. 43m. I.S.T., was the greatest of these. The earthquake was accompanied by rumbling sounds heard at places as far from the epicentre as Myitkhina in Upper Burma and in parts of Assam 450 km. from the epicentre.

The epicentre is somewhat to the N.E. of the major seismic zone of Assam and lies at the junction of the N.N.E.-S.S.W. Burma structural axes and the E.W. structural lines of the Himalayas. As a possible contributory factor to the earthquakes, doubtless occasioned by mountain building, there is a belt of negative gravity anomalies up to — 75 milligals following the lines of maximum uplift in the hills separating Assam from Burma. These anomalies may extend to the north, though the exact correlation between such anomalies and belts of earthquake epicentres is not yet definitely established.

### References


(1) Tillotson E., *Nature* (Jan. 27, 1951), **167**, p. 128.
(2) Kingdon-Ward F., *Nature* (Jan. 27, 1951), **167**, p. 130.
(3) Malurkar, *Journal of Scientific and Industrial Research, India* (1951), **10a**, No. 1, pp. 21–25.
(4) Sohoni, V. V., *Curr. Sci.* (1950), **19**, 265.
(5) Tandon, A. N., *Sci. and Cult.* (1950) **16**, 147.

# RESEARCH COMMITTEES, 1951–52

Grants of money, if any, from the Association for expenses connected with researches are indicated in heavy type.

## SECTION A.—MATHEMATICS AND PHYSICS.

Seismological investigations.—Dr. R. Stoneley, F.R.S. (*Chairman*), Lt.-Col. E. Tillotson (*Secretary*), Mr. E. F. Baxter, Miss E. F. Bellamy, Prof. P. G. H. Boswell, O.B.E., F.R.S., Mr. B. C. Browne, Dr. E. C. Bullard, F.R.S., Dr. K. F. Chackett, Dr. G. E. R. Deacon, F.R.S., Dr. A. T. J. Dollar, Rev. H. Norman Edge, Dr. A. E. M. Geddes, O.B.E., Prof. G. R. Goldsbrough, C.B.E., F.R.S., Dr. M. N. Hill, Dr. O. J. R. Howarth, O.B.E., Mr. J. S. Hughes, Prof. H. Jeffreys, F.R.S., Mr. E. N. Lawrence, Dr. A. W. Lee, Dr. A. O. Rankine, O.B.E., F.R.S., Rev. C. Rey, S.J., Dr. G. D. Robinson, Mr. H. V. Shaw, Sir Frank Smith, G.C.B., G.B.E., F.R.S., Dr. P. L. Willmore.

## SECTION C.—GEOLOGY.

To excavate critical geological sections in Great Britain.—Mr. W. H. Wilcockson (*Chairman*), Dr. G. Y. Craig (*Secretary*), Sir Edward Bailey, M.C., F.R.S., Mr. J. L. Begg, Mr. W. S. Bisat, F.R.S., Prof. P. G. H. Boswell, O.B.E., F.R.S., Prof. A. H. Cox, Dr. E. E. L. Dixon, Prof. W. G. Fearnsides, F.R.S., Prof. H. L. Hawkins, F.R.S., Prof. G. Hickling, F.R.S., Dr. R. G. S. Hudson, Prof. V. C. Illing, F.R.S., Prof. O. T. Jones, F.R.S., Dr. Murray Macgregor, Mr. T. G. Miller, Prof. L. R. Moore, Dr. F. J. North, Prof. F. W. Shotton, M.B.E., Dr. W. E. Swinton, Dr. F. S. Wallis, Prof. D. M. S. Watson, F.R.S., Prof. T. S. Westoll, Mr. T. H. Whitehead, Prof. W. F. Whittard, Prof. S. W. Wooldridge. **£20.**

To consider and report on questions affecting the teaching of geology in schools.—Sir Arthur Trueman, K.B.E., F.R.S. (*Chairman*), Dr. Mabel E. Tomlinson (*Secretary*), Miss M. A. Arber, Mr. A. Bray, Prof. A. H. Cox, Miss Gaynor Evans, Prof. W. G. Fearnsides, F.R.S., Prof. T. N. George, Prof. G. Hickling, F.R.S., Prof. D. E. Innes, Prof. D. Leitch, Prof. L. R. Moore, Prof. W. J. Pugh, O.B.E. F.R.S., Dr. K. S. Sandford, Dr. H. Dighton Thomas, Dr. A. K. Wells, Prof. A. Wood.

The collection, preservation, and systematic registration of photographs of geological interest.—Prof. H. L. Hawkins, F.R.S. (*Chairman*), Dr. W. S. Pitcher (*Secretary*), Mr. H. Ashley, Mr. G. M. Davies, Mr. W. G. Hardie, Dr. N. Holgate, Mr. G. S. Johnstone, Dr. A. G. MacGregor, Dr. F. J. North, Mr. J. Ranson, Mr. G. S. Sweeting, Prof. W. F. Whittard.

## SECTIONS D, K.—ZOOLOGY, BOTANY.

To consider the position of biology and rural science in the school curriculum and matters relating thereto.—Prof. L. J. Audus (*Chairman*), Dr. L. M. J. Kramer (*Secretary*), Mr. F. H. C. Butler, Dr. H. R. Fletcher, Mr. W. J. Heasman, Prof. C. T. Ingold, Prof. H. W. Miles, Dr. G. E. Newell, Mr. A. C. Penney, Prof. J. Walton, Mr. W. B. Yapp. **£10.**

Co-ordinating committee for Cytology and Genetics.—Prof. R. A. Fisher, F.R.S. (*Chairman*), Dr. J. L. Crosby (*Secretary*), Prof. F. A. E. Crew, F.R.S., Dr. C. D. Darlington, F.R.S., Dr. E. B. Ford, F.R.S., Dr. J. Hammond, F.R.S., Prof. T. J. Jenkin, C.B.E., Prof. K. Mather, F.R.S., Prof. L. S. Penrose, Dr. G. Pontecorvo, Dr. R. R. Race, Dr. P. T. Thomas, Dr. W. B. Turrill, Prof. C. H. Waddington, F.R.S. **£5.**

## SECTION E.—GEOGRAPHY.

To collect and record information on demography and seasonal activities in relation to environment in Inter-Tropical Africa.—Prof. A. G. Ogilvie, O.B.E. (*Chairman*), Mr. R. W. Steel (*Secretary*), Prof. S. J. K. Baker, Mr. K. Buchanan, Dr. R. J. Harrison Church, Prof. F. Debenham, O.B.E., Prof. C. Daryll Forde, Prof. B. J. Garnier, Dr. E. J. Howell, Mr. D. B. Mather, Dr. R. Miller, Prof. W. J. Varley, Prof. J. H. Wellington. **£5.**

To prepare a glossary of geographical terms with agreed definitions in English including reference to origin and previous usage and to current use and misuse.—Prof. E. G. R. Taylor (*Chairman*), Mr. J. C. Swayne (*Secretary*), Mr. G. R. Crone, Prof. W. G. East, Mr. F. George, Mr. E. O. Giffard, M.B.E., Mr. A. F. Martin, Dr. C. J. Robertson, Mr. A. E. Smailes, Mrs. J. A. Steers, Mr. G. T. Warwick, Prof. S. W. Wooldridge. **£10.**

## SECTION H.—ANTHROPOLOGY.

To co-operate with the Torquay Natural History Society in investigating Kents Cavern.—Mr. M. C. Burkitt (*Chairman*), Prof. F. E. Zeuner (*Secretary*), Mr. A. L. Armstrong, Prof. V. G. Childe, Prof. D. A. E. Garrod, Mr. A. G. Madan, Dr. K. P. Oakley, Mr. E. Pyddoke. **£10.**

To co-operate with a committee of the Royal Anthropological Institute in the exploration of caves in the Derbyshire district.—Mr. M. C. Burkitt (*Chairman*), Mr. A. Leslie Armstrong (*Secretary*), Dr. Arthur Court, Prof. H. J. Fleure, F.R.S., Prof. D. A. E. Garrod, Mr. W. H. Hanbury, Dr. J. Wilfred Jackson, Mr. R. U. Sayce.

To carry out research among the Ainu of Japan.—Mrs. C. G. Seligman (*Chairman and Secretary*), Rt. Hon. Lord Raglan, Mr. Arthur Waley.

To administer a grant for completion of work on the Bury St. Edmunds skull site.—Mr. M. C. Burkitt (*Chairman*), Dr. K. P. Oakley (*Secretary*). **£8. 16s. 8d.** (unexpended balance).

To consider the possibility of archaeological work on vacant sites in the city of Leicester.—Prof. I. A. Richmond (*Chairman*), Dr. D. B. Harden (*Secretary*), Mr. Philip Corder, Mr. A. Leslie Armstrong, Mr. D. T.-D. Clarke, Mr. K. D. M. Dauncey, Mr. D. M. Waterman.

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